Project n°.AURG/2/161

(Contract AURG/161/2012)

Aval Fonio

Improvement of post-harvest and enhancement of fonio in Africa

Annual report

(January 2015 – June 2016)

Authors: **Cruz** Jean-François, **Goli** Thierry, **Ferré** Thierry, **Thaunay** Patrice

Project coordinator : CRUZ Jean-François

CIRAD (Centre de Coopération internationale en Recherche Agronomique pour le Développement - France)

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Cover photo: Training in the use of the cross flow dryer *CSec-T* in Burkina Faso (© T.Ferré, Cirad)

Contents

1. Description

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1.4. Title of the Action:

Improvement of post-harvest and enhancement of fonio in Africa (“Aval Fonio”)

1.5. Contract number: AURG/161/2012

1.6. Start date and end date of the reporting period:

January 2015, June 2016

1.7. Target countries or regions:

Guinea, Mali, Burkina, Senegal (and Burundi)

1.8. Final beneficiaries and/or target groups[1]:

Final beneficiaries: African fonio commodity chain stakeholders, especially women

Target groups: Producers from Fouta Djallon (Guinea) – Women’s processing groups and SMEs in Burkina Faso, Mali and Senegal - Local equipment manufacturers. National Research Systems in Guinea, Mali, Burkina Faso, Senegal (and Burundi)

1.9. Countries in which the activities take place (if different from point 1.7):
Guinea, Mali, Burkina, Senegal

[1] Target groups” are the groups/entities who will be directly positively affected by the project at the Project Purpose level, and “final beneficiaries” are those who will benefit from the project in the long term at the level of the society or sector at large.

1.10. Action structure

The Action, which is based the complementarity of the partners and their knowledge of the fields of operation, is organised in 5 *work packages* (WPs), described in detail below, and illustrated schematically in Figure 1, which also shows the target groups.

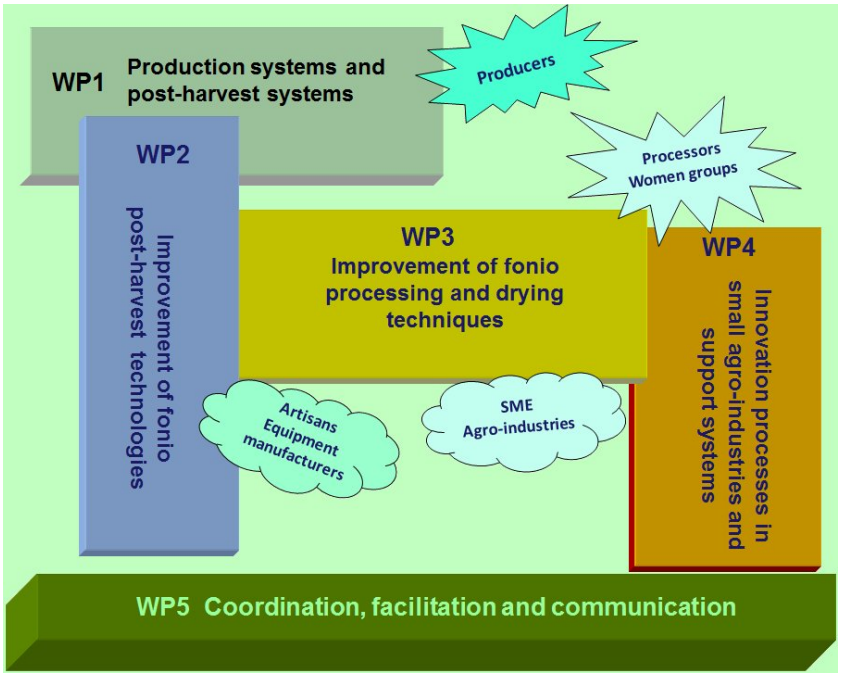


Figure 1. Work packages schematic

The main activities are illustrated in the diagram below (Figure 2).

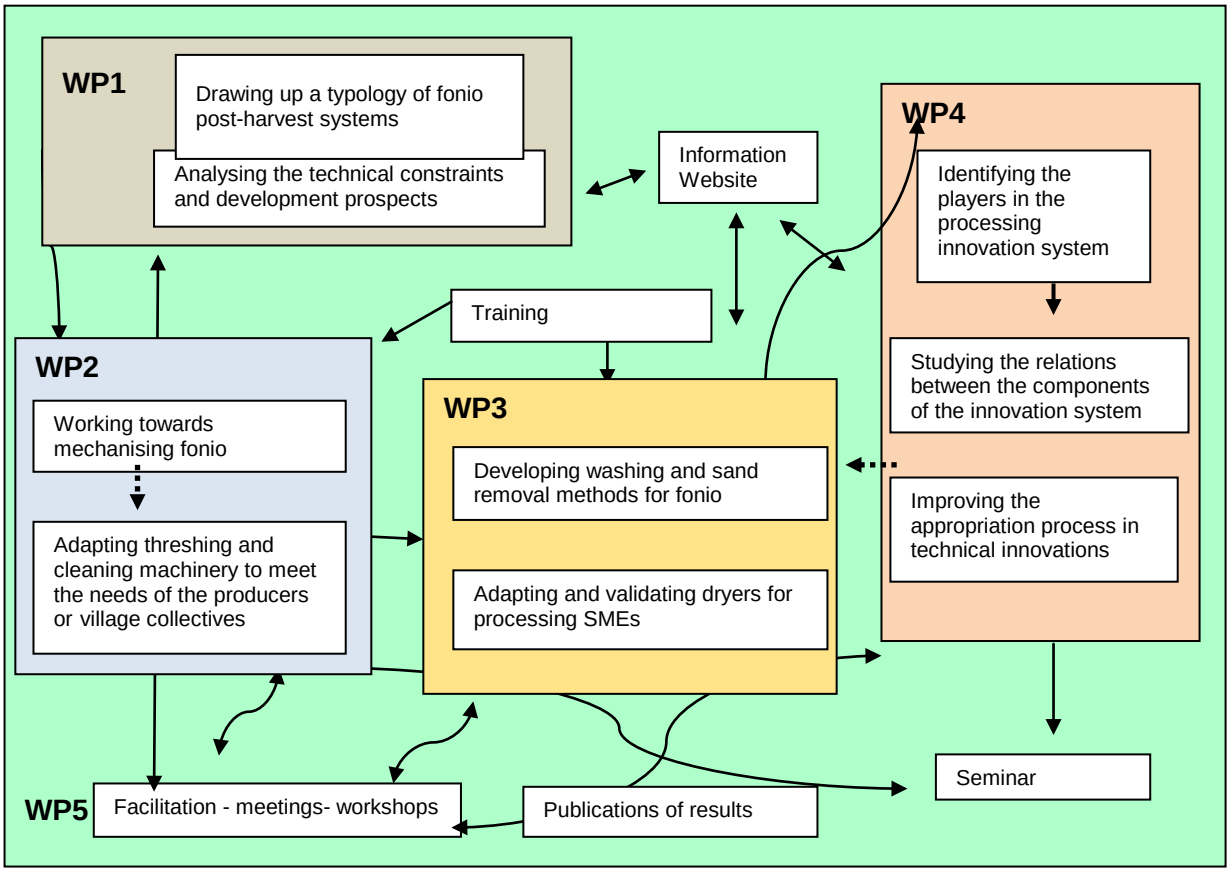


Figure 2. Diagram of the main activities of the Action

2. Assessment of implementation of Action activities

2.1.Executive summary of the Action

The Aval Fonio project (AURG/161/2012), which was originally due to run until 16 December 2015, was extended by 6 months until 16 June 2016 (African Union addendum no.1 of 5 October 2015 changing the project term to 42 month). In 2015, the second annual meeting was held in Ouagadougou (Burkina Faso) from 19 to 23 January 2015. This meeting brought together ten or so participants from Mali, Senegal, Burundi France and naturally Burkina Faso. Only the IRAG researchers (Guinea) were unable to travel to the meeting. Then, from 8 to 12 June 2015, a work packages workshop bringing together twenty or so participants was held in Dakar (Senegal). In the first half of 2016, the third annual meeting was held in Dakar (Senegal) from 1 to 5 February 2016. This meeting brought in a dozen participants. In the end, the final meeting was held in Montpellier (France) from 6 to 10 June 2016, bringing together all the project partners except for Burundi.

In 2015 and 2016, the WP1 activities in Guinea: "Analysing production and post-harvest systems" initiated in 6 large villages in Fouta Djalon were extended to the areas of Lélouma and Mali, situated to the west and north of Labé. These prefectures were chosen since fonio cultivation is very frequent there, both in tapades and in outfields.

For WP2 "Mechanisation of post-harvest techniques", trial plots were planted at IRAG Bareng in July 2015. After modification, the fonio motor mower was tested in Guinea, but the results were dissatisfactory. Fonio threshing and cleaning tests were carried out by IRAG. The Ricefan thresher (Votex) purchased from IMAF in Bamako (Mali) was tested, but the results were mediocre. The new trials conducted with the reconditioned ASSI thresher confirmed the good results already obtained during the previous fonio projects. The cleaning trials with the rotary screen and winnowing channel also confirmed the good performances of this equipment.

Regarding WP3 "Improving processing and stabilisation techniques", and activity 3 (mechanisation of washing and degritting), it was concluded that washing could be mechanised using a simple electrical "cement mixer". For degritting, Cirad designed and built a first "hydrolift" prototype degritter, which was assembled at the IMAF workshop before being installed on the premises of Ucodal in Bamako. The equipment has operated since summer 2015 under actual conditions of use with good performances: a throughput of 80 to 100 kg/h and a residual grit content in the grains down to 200 mg/kg or even less. In view of the good performances obtained, a series of 3 hydrolifts was made for field testing on the premises of SMEs in Bamako (Mali), Bobo Dioulasso (Burkina Faso) and Kédougou (Senegal). Regarding activity 4 "drying", a cross-flow dryer (CSec-T) and a "greenhouse" dryer (CSec-S) were fitted with instrumentation and tested in early 2015 on the ESP-UCAD site in Dakar. Then in late 2015, these dryers were transferred to the field: a CSec-S greenhouse dryer at the Koba Club group (Kédougou), and a CSec-T cross-flow dryer to the Salémata group (eastern Senegal).

For WP4 "Innovation process in small processing plants", the work conducted during the latter phase of the project furthered knowledge of the key players and stakeholders in the fonio industry innovation system in Burkina Faso and Mali. The "GMBF fonio huller" innovation case study reveals significant impacts on all the industry players, and primarily on the women processors and the producers. In Burkina Faso, a multi-player innovation platform system to support the dissemination of the "Hydrolift" and "CSec-T" dryer innovations was set up in 2015 in Bobo Dioulasso. The company SOLDEV, a major player on this platform as an equipment manufacturer, has already manufactured and sold 5 dryers for women fonio processors in Ouagadougou, Bobo Dioulasso and Banfora.

For WP5, the Coordinators organised the various researchers' workshops and the annual meetings of the Steering Committee, especially in January 2015 in Ouagadougou (Burkina Faso), in June 2015 and February 2016 in Dakar (Senegal), and finally in June 2016 in Montpellier (France). The project website (http://aval-fonio.cirad.fr/en) has been regularly updated. The coordination also published the book "Fonio, an African cereal" (Cirad –IRAG Edition) and produced a short documentary film titled "fonio".

Résumé de l'Action (French summary)

Le projet Aval Fonio (AURG/161/2012) qui devait initialement durer jusqu'au 16 décembre 2015 a été prolongé de 6 mois jusqu'au 16 juin 2016 (addendum n°1 de l'Union Africaine du 5 octobre 2015 portant la durée du projet à 42 mois). Au cours de l'année 2015, la deuxième réunion annuelle a été organisée à Ouagadougou au Burkina Faso du 19 au 23 janvier 2015. Cette réunion a réuni une dizaine de participants venant du Mali, du Sénégal du Burundi, de France et naturellement du Burkina. Seuls les chercheurs de l'IRAG (Guinée) n'ont pas eu la possibilité se joindre à la réunion. Puis, du 8 au 12 juin 2015, un atelier des workpackages rassemblant une vingtaine de participants s'est tenu à Dakar au Sénégal. Au cours du premier semestre de l'année 2016, la troisième réunion annuelle a eu lieu à Dakar au Sénégal du 1 au 5 février 2016. Cette réunion a été suivie par une douzaine de participants. Enfin la réunion finale s'est déroulée à Montpellier (France) du 6 au 10 juin 2016 et a réuni tous les partenaires du projet à l'exception du Burundi.

En 2015 et 2016, les activités du WP1 en Guinée : « Analyse des systèmes de production et des systèmes post-récolte» initiées dans 6 gros villages du Fouta Djalon ont été étendues aux zones de Lélouma et Mali situées à l'ouest et au nord de Labé. Ces préfectures ont été choisies car la culture du fonio y est très fréquente aussi bien dans les tapades que dans les champs extérieurs.

Pour le WP2 « Mécanisation des techniques post-récolte », des parcelles d'essais ont été mises en culture à l'IRAG Bareng en juillet 2015. Après modification, la motofaucheuse à fonio a été testée en Guinée mais les résultats n'ont pas donné satisfaction. Des tests de battage et de nettoyage du fonio ont été réalisés par l'IRAG. La batteuse type Ricefan (Votex) achetée à la Société IMAF de Bamako (Mali) a été testée mais les résultats sont médiocres. Les nouveaux essais réalisés avec la batteuse ASSI réhabilitée, ont confirmé les bons résultats déjà obtenus lors des précédents projets fonio. Les essais de nettoyage avec le crible rotatif et le canal de vannage ont également confirmé les bonnes performances de ces équipements.

Concernant le WP3 « Amélioration des techniques de transformation et de stabilisation », et l'activité 3 de mécanisation du lavage et du dessablage, il a été conclu que l'utilisation d'un simple laveur type «bétonnière» électrique permettait de mécaniser le lavage. Pour le dessablage, le Cirad a conçu et construit un premier prototype de dessableur « hydrolift » qui a été assemblé dans l'atelier IMAF avant d'être installé à la société Ucodal de Bamako. Le matériel fonctionne depuis l'été 2015 dans des conditions réelles d'utilisation avec de bonnes performances : débit de 80 à 100 kg/h avec un taux de sable résiduel dans le fonio qui peut être inférieur à 200 mg/kg. Au vu des bonnes performances obtenues une série de 3 hydrolifts a été réalisée pour être testée en milieu réel dans des petites entreprises de Bamako (Mali), Bobo Dioulasso (Burkina Faso) et Kédougou (Sénégal). Concernant l'activité 4 « séchage », les séchoirs à flux traversant (CSec-T) et serre solaire (CSec-S) ont été testés en station au Sénégal. Le séchoir CSec-T a une capacité de chargement d'environ 100 kg et un débit de séchage de 30 à 35 kg/h (séchage de fonio humide de 35% à 10%). Un séchoir CSec-S de 90 m² équipé de 10 claies assure le séchage d'environ 300 kg de fonio en 24 h (séchage de fonio humide de 35% à 10%). Certains de ces séchoirs ont été transférés et validés en milieu réel au Sénégal (séchoirs à flux traversant et serre solaire), au Burkina Faso (séchoirs à flux traversant) et en Guinée (petit séchoir serre solaire).

Pour le WP4 « Processus d'innovation dans les petites industries de transformation », les travaux réalisés au cours de la dernière phase du projet ont permis d'approfondir la connaissance des acteurs clés et des parties prenantes du système d'innovation de la filière fonio au Burkina Faso et au Mali. L'étude de cas de l'innovation « décortiqueur de fonio GMBF » met en évidence des impacts significatifs sur l'ensemble des acteurs de cette filière et en premier lieu les transformatrices et les producteurs. Au Burkina Faso, un dispositif, de type plateforme d'innovation multi-acteurs, pour soutenir la diffusion des innovations « Hydrolift » et « séchoir CSec-T » a été mis en place en 2015 à Bobo Dioulasso. L'entreprise SOLDEV, acteur majeur de cette plateforme comme équipementier, a déjà fabriqué et commercialisé 5 séchoirs pour des transformatrices de fonio de Ouagadougou, de Bobo Dioulasso et de Banfora.

Pour le WP5, la coordination a organisé les différents ateliers de chercheurs et les réunions annuelles du comité de pilotage et notamment en janvier 2015 à Ouagadougou au Burkina Faso, en juin 2015 et en février 2016 à Dakar au Sénégal et finalement en juin 2016 à Montpellier (France). Le site Web du projet (http://aval-fonio.cirad.fr/) a été régulièrement actualisé. La coordination a publié l'ouvrage «Fonio, an african cereal» (Edition Cirad –IRAG) et a produit un petit film documentaire intitulé « Fonio ».

2.2. Activities and results

2.2.1. **WP1: Analysis of production and post-harvest systems**

Activity 1.1. *Typology of production systems and associated post-harvest systems*

This activity was coordinated by Dr Béavogui Famoï (IRAG), and carried out by IRAG agents under the supervision of Mr. Camara Sawa and the intern Ms. Diallo Aïssatou.

✓ ***Surveying***

The surveys conducted in 2013 and 2014 in 6 large villages in Fouta Djalon were extended, in 2015, to the prefectures of Lélouma and Mali situated to the west and north of Labé, respectively. These prefectures were chosen since fonio cultivation is very frequent there, both in tapades and outfields. The surveys were conducted in villages and on farms.

Table 1. List of village surveyed

Prefecture	Village
Mali	Donghel Sigon and Fougou
Lélouma	Lélouma urban community and Diountou

The villages are for the most part situated on hillsides, or sometimes mountainous areas, with gravelly soil.

✓ ***Survey results***

Fonio cultivation is very common in both prefectures, under one of two production systems, “tapades” and “outfields”.

- Tapades[2] are enclosed cultivated areas. Contrary to our observations in the prefectures of Labé, Pita, Dalaba and Mamou, where fonio is very uncommon in tapades, in the areas of Mali and Lelouma, fonio is very commonly cultivated in this part of the farms, since it is present in 50% of cases. The tapade remains the special preserve of the women, who above all use it to grow fruit and vegetable crops. Fonio is sown there upon the first rains with extra-early varieties (80 to 90 days), to ensure a harvest for the “lean season”. According to certain producers fonio is used as the first crop to mark occupation of the soil, and limit weed growth. In the “tapade system”, as soon as soil fertility has been restored in the plots, fonio cultivation is often abandoned in favour of maize or other food crops (taro, sweet potato, vegetables).

Figure 3. Early fonio within a tapade in Mali prefecture (© S. Camara, IRAG)

[2] Tapade: an enclosure within a farm in Fouta-Djallon, Guinea. The word tapade is a Franco-Guinean term, apparently derived from the Portuguese tapar: close

- Outfields", which elsewhere are the prerogative of the men, are very often cultivated here by women, who represent nearly 45% of farmers. These women have taken over farms because of the high migration by the men to the mining areas of Guinea (Fria, Kamsar, Siguiri, etc.), Senegal, Europe and even the United States. The outfields are used above all for fonio cultivation, which represents 75 % of cultivated surface areas. Fonio is the main crop on all the farms, ahead of maize, cassava, the peanut and dry-land rice. As in the other areas of Fouta Djalon, there are three distinct types of farm by ecological zone: plain fonio (45 %), hillside fonio (45 %) and mountain fonio (10 %).

There are three distinct types of farm by ecological zone: plain fonio, hillside fonio and mountain fonio.

Plain fonio

This ecological zone primarily relates to the village of Donghel Sigon, which has large homogenous expanses of vegetation on acidic soils (pH<5), poor in organic materials. This village has two big enclosed areas of 170 ha and 250 ha, which in the recent past were used for growing potatoes, but which are now dedicated to fonio cultivation. The potato was abandoned because of difficulties of irrigation, and of access to inputs and the market.

Figure 4. Plain fonio in the village of Donghel Sigon in Fouta-Djallon (© S. Camara, IRAG)

In these 2 areas, the producers, respectively 220 (of which 99 women) and 475 (of which 285 women), sow extra-early varieties (80 to 90 days) and medium-late varieties (110-130 days). The sowing, carried in July with average quantities of 50 kg/ha, is followed by 2 weeding operations in August and September. The harvests are then staggered from October to November, with yields of around 550 kg/ha. This ecological zone, on poor soil, is characterised by fonio monoculture for 5 to 10 years followed by a fallow period of equivalent duration.

The ploughing, sowing, weeding, harvesting and threshing work are mainly manual, and require a significant external workforce (mutual assistance or employing casual labourers).

It is mainly for plain fonio that harvest mechanisation is most feasible.

Hillside fonio

This system is characterised by well-drained gravelly soils where fonio is cultivated alongside the peanut, cassava and rice. It represents 45 % of the new farms surveyed. On farms with a surface area of 1 to 2 ha, producers sow fonio after growing rice for one or two years.

After working the soil in June, fonio is sown in July in average quantities of 40 kg/ha, followed by manual weeding only, often carried out by the women. Because of the low water retention capacity of the soil, the producers use extra-early varieties (80 to 90 days), which thereby ensure a harvest in the "lean" season.

The harvests are staggered from August to October, with yields of around 700 kg/ha. Mechanisation of ploughing and harvesting is a difficult proposition, because of the presence of stones and tree stumps in the fields.

Figure 6. Hillside fonio in the village of Fougou, Fouta-Djallon (© S. Camara, IRAG)

Mountain fonio

This system is characterised by steep terrain which has been cleared (slash-and-burn clearing from February to April) for growing dry-land rice, peanut, sorghum and fonio. It represents approximately 10 % of the farms surveyed. Rice is always the first rotation crop, often followed by fonio from the second year.

On the farms, which have an average surface area of 0.7 ha, the producers sow extra-early varieties (80 to 90 days) and medium-late varieties (110-130 days). Sowing is carried out in June & July in average quantities of 30 kg/ha. The harvests are then staggered from August to October, with yields often in excess of 1000 kg/ha.

As with the hillside fonio, mechanisation of ploughing and harvesting is a difficult proposition because of the steep slopes and the presence of stones and tree stumps in the fields. Because of the heavy constraints on field work, this ecology zone is dominated by men

Figure 6. Mountain fonio in the village of Fougou, Fouta-Djallon (© S. Camara, IRAG)

✓ ***Main observations***

Rotations

In the four villages in the two prefectures surveyed, the main rotations employed by producers vary between the systems, as shown by table 2 below:

Table 2. Crop rotation systems by ecology

Cropping system	Rotation
Tapade	• Fonio - peanut - potato • Maize - cassava - taro • Cassava - maize - cassava - maize - peanut • Fonio - cassava - maize
Outfields	• Fonio - peanut • Fonio - cassava - maize - peanut • Cassava - peanut - cassava • Peanut - fonio • Peanut - maize - fonio

Crop rotation

In the outfield system producers apply crop rotation for all the ecological zones. Table 3 below presents the main rotation systems for the farms surveyed.

Table 3. Calendar of cultivation operations by ecological zone

Ecological zone	Rotation system
Plain	Fonio-fonio-fonio-fonio for more than 10 years in succession
Hillside	Fonio-fonio-fallow or rice-fonio-fonio-fallow
Mountain	Rice-rice-fonio-fallow or Fonio-fonio-fallow or rice-fonio-fonio-fallow

Gender aspect

Contrary to the observations made in previous studies, where the outfield production system was dominated by men, women are strongly represented in outfield fonio cultivation in the Mali and Lélouma prefectures, with a figure of 44% as opposed to 56% for men. These women are generally the wives of men away from home due to the high migration among this social stratum.

Activity 1.2. *Main producer constraints, and prospects*

The main difficulty reported by fonio producers concerns the complete absence of a concerted strategy between the public services and essential players. They lament the lack of structuring of the industry, due to which they often feel abandoned without entitlement to technical or financial support. The other main constraints encountered by producers and identified in the surveys concern on the one hand those due to production and on the other hand those relating to the harvest and post-harvest. They are of the same sort as those already identified in the other prefectures surveyed in the previous years.

✓ ***Production constraints***

The main constraints reported by producers in terms of fonio cultivation relate firstly to soil quality. On the plains, the soils are regarded as very poor because of fonio monoculture for 5 to 10 years in succession. Some producers in Lélouma prefecture consider that fonio needs fertiliser inputs, and so cultivate fonio after a prior crop of potatoes. In the hillside and mountain zones, cultivation is made difficult by the steepness of the terrain and the presence of stones.

Weeds, attack by birds or wild animals (monkeys), but above all the presence of termites, are constraints frequently mentioned by fonio producers.

Degenerescence of varieties is also a factor which contributes to limiting fonio cultivation. According to certain producers, the seeds used now produce only low yields, and nearly 80% say that they have abandoned the late varieties with more than 130 days' vegetation.

In view of the lack of family labour (high migration by young people) and the high maintenance workload (ploughing, weeding, etc.), producers had a lot of complaints about the dilapidation of the agricultural tools and the low level of agricultural mechanisation.

Finally, the long distances to travel between villages and outfields on poorly maintained rural tracks represent a brake to the development of fonio cultivation.

✓ *Harvesting constraints*

On all the farms, fonio harvesting is still an exclusively manual operation. In the villages surveyed, this operation is often performed by Fulani women using rudimentary tools such as the sickle or knife (figure 7).

1- Sickle

2 – Knife

Figure 7. Fonio harvesting tools (© S. Camara, IRAG)

According to producers, manual harvesting remains a highly painstaking operation, especially because of lodging of fonio upon maturity (figure 8). Furthermore, transport and stacking of the sheaves before threshing (figure 9) reportedly cause significant but unevaluated losses. These various constraints are leading certain producers to reduce the cultivated surface areas, or even abandon fonio cultivation.

Figure 8. Harvesting by sickle (© S. Camara, IRAG)

Figure 9. Stack of sheaves (© S. Camara, IRAG)

✓ *Post-harvest constraints*

In the surveyed villages, threshing which consists in separating the grains from the panicles is generally performed by trampling or crushing underfoot (figure 10). Supporting themselves on a horizontal bar or on rods, the women or children rub the sheaves one by one between their feet to separate the grains from the stem.

Yet the producers, especially the women, still consider the most painstaking and the most loss-causing operation to be hulling-whitening, which remains to this day the main bottleneck for the industry. Indeed, traditional hulling, carried out using a pestle and mortar by women, is highly unproductive, with just a few kilogrammes of paddy fonio processed per hour.

Figure 10. Fonio threshing by crushing underfoot (© S. Camara, IRAG)

Note: Under the Aval Fonio project, the producers from the village of Donghel Sigon participated in mechanical threshing trials. To promote mechanical hulling of fonio in the zone, they were provided with a GMBF huller.

Generally speaking, the producers lament the low level of distribution of threshing, cleaning and hulling equipment developed by research over the past decade. The absence of mechanisation of the post-harvest operations in most of the surveyed zones forces many producers to employ labour from outside the family. Yet this labour is increasingly scarce because of the high migration of young people to employment hotspots outside the region.

Under previous Fonio projects, Guinea has participated in adapting the ASSI thresher and developing cleaning equipment (rotary screen and winnowing channel) and hulling equipment (GMBF fonio huller). Yet the manufacture and distribution of all this equipment is practically non-existent in Guinea, while it is starting to become very widespread in Mali, Burkina Faso, Senegal and throughout West Africa.

✓ *Trade constraints*

The landlocked position of the big production zones in Middle Guinea (Mali, Lélouma, etc.) and the poor condition of the communication routes (rural tracks) are major brakes on fonio trade. They generate high transport and handling costs in taking the fonio to the villages, where the collection markets are held to supply the big market in Mitty (Dalaba prefecture). The lack of threshing equipment and processing equipment (hullers) prevents producers from trading as much hulled fonio as they would like.

✓ *Prospects*

Despite the various constraints impeding producers, there are many reporting an increase in fonio production. In the surveyed regions, this positive result could be due to potato and fonio crop rotations, to following the cropping calendar or to applying longer fallow periods (5 to 10 years).

Fonio production can be improved by implementing rational cultivation techniques, with in particular a choice of varieties tailored to the ecological zones and to consumer preferences, good soil preparation, possibly using inputs, and finally following a cropping calendar with good crop rotations.

Improving rural transport should also enable producers to increase their quantities traded on the collection markets.

Yet the most important factor is definitely the development of harvest mechanisation (where possible, such as on the plains zone) and mechanisation of post-harvest operations such as threshing, cleaning and hulling-whitening. Better recognition of the industry by institutional and financial support should help encourage the various operators to earn better value from this cereal, which is an icon of Guinea.

2.2.2. **WP2: Mechanisation of fonio post-harvest techniques**

The various actions carried out under this work package were under the responsibility of Thierno Alimou Diallo (IRAG) and Patrice Thaunay (Cirad), co-supervisors of WP2, with the collaboration of Ousmane Tanou Bah (IRAG).

Activity 2.1. *Mechanising the harvesting of fonio*

New 1 ha trial plots were planted by IRAG in July 2015 with the varieties Niathia (early), Rané (medium-late) and Konso (late). The varieties and sowing date were chosen so that the harvest could be carried out in November 2015.

The no.2 motor mower (model JD 170 F) was shipped to the IMAF workshop in Bamako (Mali) in July 2015 for modifications to be made to the cutting bar. The return of the machine to the IRAG Bareng Centre (Guinea) was delayed, and so the trial plots had to be harvested manually. So the field mowing tests were conducted on a producer's plot (figure 11). The trials showed that the motor mower cuts the stems but does not discharge the sheaves on the side of the machine. The straw gets entangled around the rotors, and causes jams (figure 12). So studies are required to address the mechanisation of fonio harvesting in the long term.

Figure11. Mechanised mowing test on a smallholding (© IRAG)

Figure12. Entangled straw (© IRAG).

Activity 2.2. *Adapting the threshers and cleaners*

✓ ***Threshers***

Ricefan thresher

A Ricefan thresher (Votex), manufactured by IMAF (Bamako) in 2014, was first tested by the IER/LTA team with the following results:

- Mass of sheaves: 502 kg; mass of threshed grains: 114 kg, threshing time: 1 hour 36 mins

I.e. a throughput of approximately 310 kg/h of sheaves and 70 kg/h of threshed grains. The threshed product obtained contained more than 20 % various impurities such as straw and chaff.

Figure 13. Ricefan thresher trial (© IRAG).

This machine was then delivered to IRAG Bareng in June 2015, and the tests were conducted in November 2015 after the fonio harvest (figure 13). The threshing tests obtained an average throughput of approximately 73 kg per hour, with 18% impurities and 11 % unthreshed grains. It is regrettable that this machine discharges nearly ¾ of the grains at the straw outlet. So during threshing the majority of the grains are carried through with the straw after entering the thresher-fan drum.

The substandard performances of the Ricefan thresher (low throughput, incomplete threshing, grains mixed with straw, etc.) convinced the researchers of the need to recondition the ASSI thresher.

ASSI thresher

The ASSI (Adrao, Saed, Sismar, Isra) is a rice thresher derived from IRRI axial threshers. It is in particular manufactured in Senegal by SISMAR (Société Industrielle Sahélienne de Mécanique de Matériel Agricole et Représentation), but also by various local tradesmen.

Under the first fonio project, an ASSI thresher was purchased and tested by IRAG and Cirad in 2001. To adapt it to threshing fonio, the following modifications were made:

- ✓ Fan pulley replaced to reduce the fan speed, 100 mm pulley replaced by a 125 mm pulley, with a belt tensioner fitted.
- ✓ Distance between the fingers and the counter-thresher adjusted from 10 to 8 mm.
- ✓ Screen connecting rod shortened.
- ✓ Modifications to the cleaning system:

  - Upper grille: perforated plate (diameter 2 mm), grille extended by 450 mm to protrude past the mobile shutter

  - Lower grille, with a 1 mm mesh fitted under the lower deflector.

The performances in the trials conducted in Guinea in 2001 were very good, with an average throughput varying between 250 kg/h and 300 kg/h, and an excellent threshing quality.

Under the Aval Fonio project, the reconditioning of the machine consisted in refitting it with an engine, replacing the thresher teeth and refitting a set of grilles tailored to fonio. After initial workshop trials, the thresher was transported to the village of Donghel Sigon (Fouta Djallon) for a field operation demonstration trial.

Figure 14. Fonio mechanical threshing trial/demonstration in Donghel Sigon (© S. Camara, IRAG)

The ASSI thresher trials obtained an average throughput of 240 kg/h of fonio grains, equivalent to more than 600 kg/h of sheaves. It validated its good threshing performances, since the bulk of the grains was recovered at the main outlet, with less than 2% impurities. The quantity of unthreshed grains was estimated at less than 5 %. The quality of threshing was deemed highly satisfactory by the producers.

Figure 15. ASSI thresher (© S. Camara, IRAG)

Figure 16. Clean threshed grains (© S. Camara, IRAG)

Partial conclusion

The ASSI thresher may be perfectly suitable for threshing fonio, with a few modifications described above. This robust machine is able to obtain a threshed grain throughput of around 250 to 300 kg/h, with a very high threshing quality (few unthreshed grains, few impurities).

To evaluate the cost of motorised threshing with an ASSI thresher, a simulation was conducted, adopting the hypothesis of a tonnage of approximately 100 T of threshed fonio per year, in 90 days' operation. This simulation led to a threshing cost of approximately 15 FCFA (€0.02) per kg of threshed fonio.

Following on from the very good results obtained with the modified ASSI thresher, the mechanisation specialists have validated the machine for threshing fonio, and also take the view that it seems economically profitable, especially under conditions in Guinea. Threshers are relatively expensive machines which can often only turn a profit on a contracting basis. This equipment should be affordable to village associations or outsourcing contractors.

The current machine, a relatively bulky piece of equipment, may be suitable for easily accessible plain zones. For mountain zones, the same type of thresher would be needed, but more compact in size, to be more easily transportable.

✓ *Cleaners*

An Alvan Blanch **winnower** (figure 17) was restored to working order by IRAG in 2013 for the purpose of paddy fonio cleaning trials. This equipment comprises a fan, a hopper and an alternating-motion cleaning unit, with two grilles mounted horizontally and a third sloping grille for eliminating particles smaller than the grains (figure 18). The grains drop out of the hopper onto the horizontal grilles, which are ventilated by a horizontal air flow produced by the fan. The straw is carried away while the grains pass through the first two grilles. After cleaning, the separated products are directed to outlet orifices for collection.

In 2014, the equipment was modified in the workshop of Mr. Thierno Bela in Labé. A chassis was fitted to enable the machine to be driven by an engine. The trials conducted at IRAG Bareng in 2015 achieved a throughput of around 400 kg/h, with good cleaning quality.

Figure 17. Alvan Blanch winnower (© J-F Cruz, Cirad)

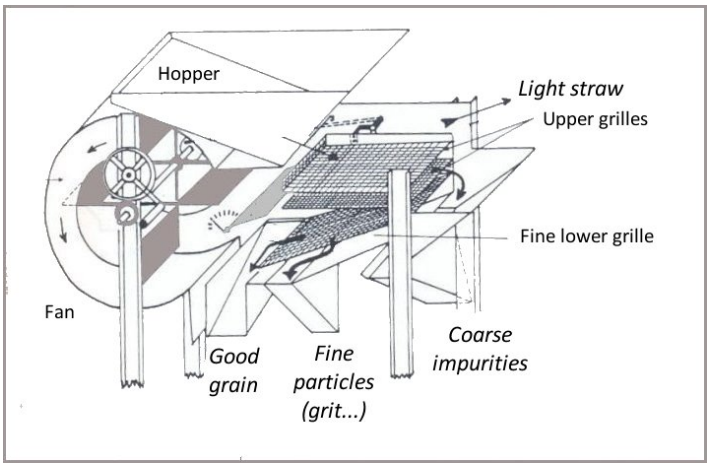


Figure 18. Diagram of a winnower (© J-F Cruz, Cirad)

A **winnowing channel** and a **rotary screen** were purchased on behalf of IRAG in 2013. This equipment was designed by Cirad under the first fonio project. They were manufactured by the manufacturer IMAF in Bamako (Mali), and were delivered to the IRAG Bareng Centre in January 2014.

The winnowing channel is a piece of cleaning equipment comprising a vertical duct with air upflow, into which the dirty product to be cleaned is introduced halfway up. The light particles are carried away by the air flow, and collected in a cyclone (figure 19). The grains and heavier particles drop into the lower part of the channel. The winnowing channel can be used immediately downstream of the GMBF huller, or on its own, equipped with a removable hopper. So it is suitable for cleaning fonio, but also winnowing other cereals.

The rotary screen comprises a slightly tilted cylindrical screen with two successive grilles (figure 20). The screen is equipped with a feed hopper, and can be driven manually (crank) or by an electric motor.

Figure 19. Winnowing channel (© C. Marouzé, Cirad)

Figure 20. Rotary screen (© M. Rivier, Cirad)

The trials carried out at IRAG Bareng confirmed the good performance of the equipment, with average throughputs of around 400 kg/h.

Partial conclusion

The winnower is a classic piece of cleaning equipment ideally suited to use for cleaning fonio, employing grilles and ventilation flowrates tailored to this tiny cereal. The winnower is versatile and has the advantage of running even with straw-laden products. Its operating principle, consisting in alternating motion of the grilles, does make it delicate to use, so the more robust rotary cleaners are often preferred.

In light of the very good results obtained (throughput around 400 kg/h) with the winnowing channel and rotary screen under previous fonio projects, and confirmed by the Aval Fonio project, the mechanisation specialists have validated this equipment for cleaning paddy fonio, and take the view that it can be used for cleaning hulled and whitened fonio; the winnowing channel is also often coupled to the GMBF huller-whitener in order to clean the product after processing.

These two machines are versatile, and can be used on cereals other than fonio. Now both machines should be makeable by local tradesmen, to ensure their distribution across a range of West African countries.

2.2.3. **WP3: Improvement of fonio processing and stabilising techniques**

The various actions carried out under this work package were under the responsibility of Thierry Goli (Cirad), Cheikh Mouhamed Fadel Kébé (ESP-UCAD) and Ms. Bore Fanta Guindo (IER), co-supervisors of WP3.

Activity 3. *Developing washing and degritting methods for fonio*

This activity consists in designing, making and testing models for washing and degritting hulled and whitened fonio.

- ✓ ***Mechanisation of washing***

In 2013, a research project was conducted to seek potential improvements and analyse the expected functions during this operation, based on observation of traditional know-how. Washing consists in eliminating foreign particles and bran which remain stuck to the fonio grains after hulling/whitening and winnowing/screening. Hand mixing of fonio in large tubs filled with water obtains good separation of the bran and light particles which are removed with the supernatant contaminated water, while the grains and grit are collected by sedimentation.

In 2014, washing tests were conducted in Mali on prototype washers identified by IER. These involved a washer manufactured by the equipment manufacturer MOD Engineering, already installed on the premises of a small fonio processing company “Dado Production” in Bamako; and small washers provided by the tradesman Nana Philomène. The results obtained with these two washers were unconvincing, and the equipment was not validated.

In 2014 and 2015, the trials then switched to electrical rotary washers. The idea of using rotary washers was proposed by Cirad during the coordination mission to Bamako in March 2014, and a visit made to the premises of Ucodal. This “cement mixer” type equipment is actually well-suited to the mixing function required by fonio washing. Washing by means of standard rotary electrical washers was tested by Cirad in a pilot workshop in Montpellier (figure 21), and by IER on the premises of Ucodal in Bamako (figure 22). This model was chosen for its simplicity, its low cost and because it employs an excess water mixing principle similar to that employed in traditional manual washing.

Figure 21. Rotary washer at Cirad (© Cruz, Cirad)

Figure 22. Rotary washer trial in Mali (© IER)

The results obtained in 2014 were confirmed in 2015 at Cirad’s Agri-food Platform, as part of the development of the first prototype line of washing-degritting machines. A two-minute prewash, followed by a one or two-minute final wash, obtain a product with cleanliness compatible with the constraints of mechanised degritting further downstream. The workload level is lower than for manual washing, and the work times and quantities of water necessary are also points in favour of mechanised washing.

✓ Mechanisation of degritting

Degritting consists in eliminating the grit present in the whitened fonio grains by a series of separation operations performed using gourds. For this activity, the research actions related to:

- developing a method for measuring the quantity of grit in a fonio sample,
- design and laboratory trialling of a “hydrolift” model degritter,
- manufacture and field trialling of “hydrolift” prototype degritters.

➢ *Developing a method for measuring the quantity of grit in a fonio sample*

The method to identify must be sensitive within the range 0 to 3% grit, and have a quantification threshold of around 0.01% (w/w) in fonio. In fact, measurements made by counting under a binocular magnifier demonstrated that the hulled and whitened fonio before degritting contained approximately 3% grit, whereas the grit content of traditionally degritted fonio is around 0.01% (sensory measurement made on commercial fonio).

Figure 23. Grains of grit in whitened fonio (© J-F. Cruz, Cirad)

In 2015 and 2016, Cirad continued to investigate quantification of grit in a fonio sample. Several methods were tested:

- Calcination at 600°C (Cirad laboratory)

The method consists in calcinating the fonio, and then taking up the mixture of ash and grit in pure water. The grit is then weighed. The trials conducted demonstrated that this method was unable to assay the grit in a sample containing less than 10% grit, since below that level the ash forms a crust inseparable from the grit. This unsuitable method has been abandoned

- X-ray diffraction (European Institute of Membranes laboratory, Montpellier)

The method consists in analysing the waves diffracted by the microcrystalline material when exposed to an X-ray beam. On the assumption that the grit primarily comprises silica crystals, analysing the density and diffraction angle of the X-rays should enable us to work out the grit content. The trials conducted demonstrated that silica is present in the form of very large crystal clusters. This configuration does not enable quantification of the silica, so the method was abandoned.

- Near-Infrared Spectrometry (NIRS), Cirad laboratory

Each wavelength of NIRS radiation (0.8 to 2.5 µm) which is aimed at the fonio sample is transmitted or reflected, depending on its composition. Processing of the spectrum obtained could, using a calibration range, be used to quantify the presence of grit, with known specific absorption and reflection properties. A first trial demonstrated the possibility of separating two groups of grit contents: only the 0 to 0.01% group can be distinguished from the 0.05 to 0.3% group, over a content calibration range of 0 to 0.3%. However, it proved that this is insufficient to classify fonio samples from the degritting model tests. These actually have grit contents of between 0 and 0.1% (w/w). A degritting result of such quality is surprising and means much

more substantial trials to develop a reliable NIRS method, which would be beyond the scope of the present project.

- Silica assaying and ICP detection method (Cirad laboratory)

Methods suitable for assaying silica in plants and soils were tested. Their principle is calcination followed by acidic or alkaline digestion. The silica is then assayed by ICP (Inductively Coupled Plasma) at 1100°C. They did not yield convincing results for contents of less than 1% grit, due to the need to evaporate the hydrofluoric acid. In 2015, the analyses were reworked thanks to the acquisition of an ICP kit for direct injection of hydrofluoric acid solutions. The method of cold solubilisation with hydrofluoric acid, followed by assaying the silica by optical ICP, yielded the most consistent results (figure 24). However, for low grit contents, the silica provided by the siliceous skeleton of fonio (≈ 0.14%) may conceal the silica provided by grit. Hence the method will have low sensitivity in the grit content region of 0.01 to 0.1%. A tenfold increase in grit content will only generate an increase in silica content of 25%. However the method is potentially usable.

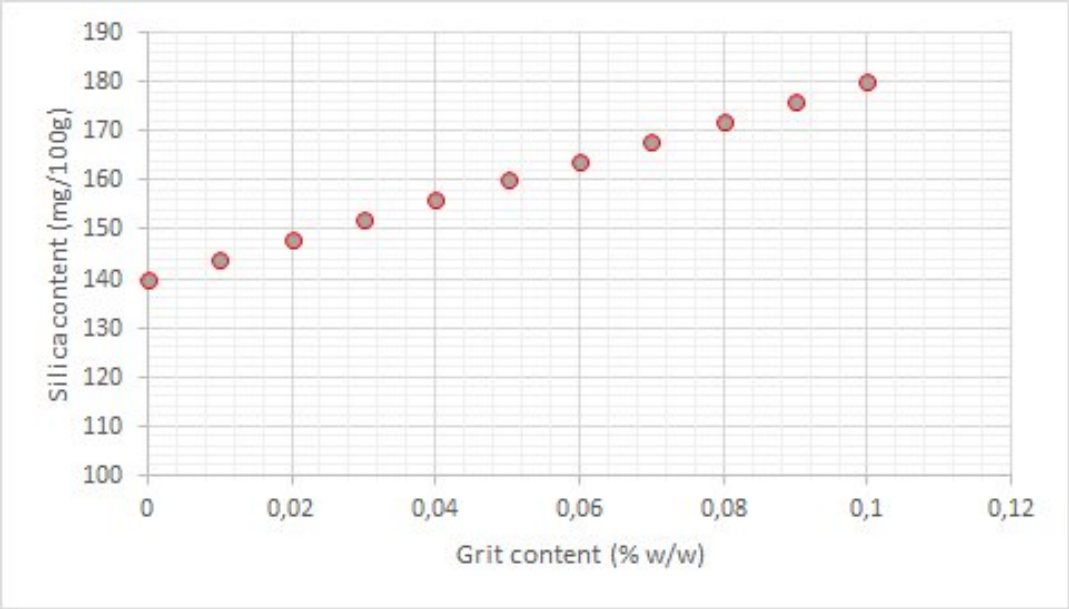


Figure 24. Silica content in 100 g of fonio, against the sample grit content (© T. Goli, Cirad)

- Silica assay method (Cirad laboratory)

Suitable methods for assaying silica in plants and soils were tested. They were based on calcination followed by acidic or alkaline digestion, of silica or organic matter respectively. The silica is then assayed by ICP (Inductively Coupled Plasma) at 1100°C. They did not yield convincing results for grit contents of less than 1%, due to the need to evaporate the hydrofluoric acid.

- Sensorial analysis method (Cirad laboratory)

This method, tested in 2014, yielded highly conclusive results. The method for determining the grit content by taste is highly sensitive, with a very low detection threshold (around zero). It is not applicable above 0.2%. It was useful for the degritting model trials at the Cirad platform in early 2015 (grit contents of 0 to 0.1%).

- Manual degritting

For analysing the quantities of residual grit obtained during the "*hydrolift*" prototype field trials, it is more efficient to perform manual degritting of the samples taken, since the local women processors are expert in separating grit from fonio.

➢ *Design and laboratory trialling of a "hydrolift" model degritter,*

The functional analysis of the degritting operation conducted in 2013 confirmed the usefulness of the principle and of the "Hydrolift" model already designed by Cirad in 2001 under the first fonio project. In 2013, a new hydrolift model was manufactured and laboratory tested.

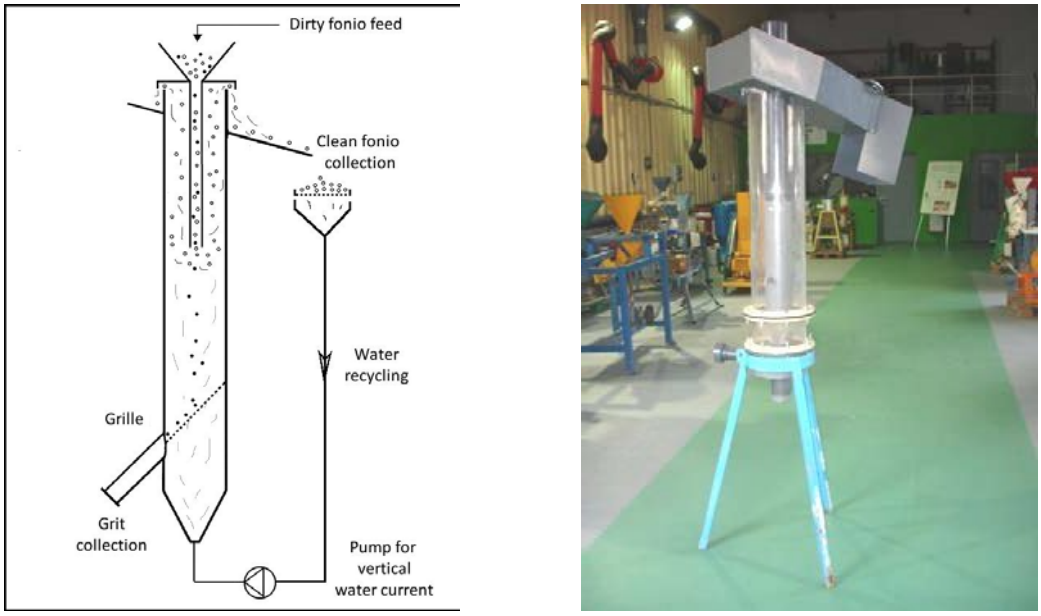


Figure 25. Schematic and model of the hydrolift (© J-F. Cruz, Cirad)

In 2014, various trials on the model were used to adjust several parameters to optimise the system hydraulics in order to homogenise the water flows in the fonio/grit separation column, and regulate the wet fonio feed.

Based on preliminary trials, an experiment plan was defined to evaluate the optimum performances of the hydrolift. It followed the protocol below:

- Determining the type of plan (complete 3^2 factorial design, with repetitions of the central point)
- Determining the influential independent variables and boundaries of the experimental domain:
  - Fonio flowrate: 70 to 130 kg/h of wet fonio
  - Water flowrate: 60 to 80 l/min.

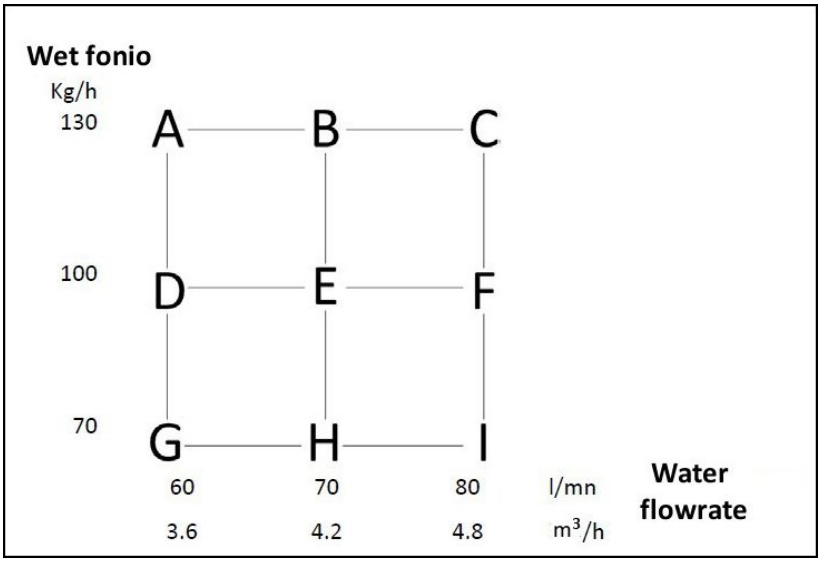


Figure 26. Diagram of experiment plan

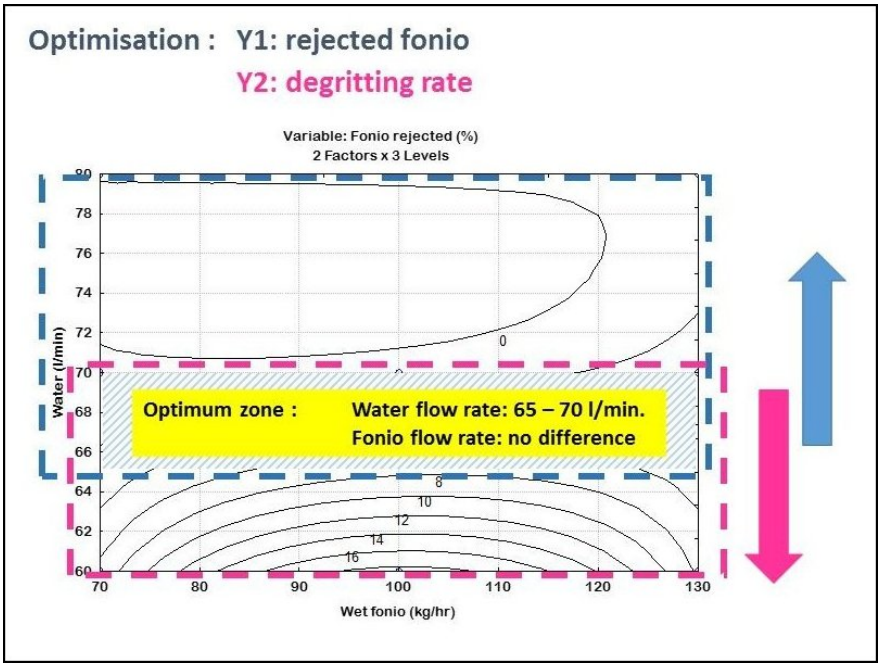
- Determining the response variables:
  - Y1 = “rejected” fonio
  - Y2 = Residual grit content in the degritted fonio

The trials were able to show the predominant effect of water flowrate in the degritting column, whereas the fonio feed flowrate had no influence on the responses, in our experimental domain. It should be noted that the main factor (water flowrate) had the following effects:

- negative on the quantity of rejected fonio (when the flowrate increases, the quantity of rejected fonio decreases)
- positive on the quantity of residual grit (when the flowrate increases, the quantity of grit in the degritted fonio increases)

Thus a compromise needs to be found, since the water flowrate factor, the hydrolift's main setting variable, has an antagonistic effect on the target objectives, namely:

- minimise the rejected fonio: blue arrow upward (figure 26)
- minimise the grit content: pink arrow downward (figure 26)



The optimum setting zones for the factors are represented by a pink dashed line for the residual grit content, and in blue for the quantity of rejected fonio.

Figure 26. Isoresponse curves: rejected fonio as a function of water and wet fonio flowrates (© T. Goli, Cirad)

Thus we can conclude that an intermediate water flowrate, of around 65 to 70 l/min, should be favoured in the prototype design to be disseminated.

A validation trial demonstrated that for a wet fonio flowrate of 130 kg per hour, and a water flowrate of 65 to 70 l/min, the following responses were obtained:

- 0.005 to 0.015% grit (w/w)
- 5 to 10% fonio rejected via the rejection outlet.

➢ *Manufacture and field trialling of "hydrolift" prototype degritters.*

- *"Hydrolift 01" prototype degritter*

The good fonio degritting results obtained in the laboratory with the experimental model provided the design basis for a first prototype ("hydrolift 01" degritter). The equipment was built in Montpellier in February 2015, and then sent to IMAF in Bamako to make the chassis and peripherals (hopper, collection vats, etc.) thereby completing the prototype assembly.

The prototype hydrolift was installed on the premises of Ucodal in Bamako for testing under actual conditions of use. The first trials, conducted in April-May 2015 during a Cirad mission with the support of IER researchers and technicians, obtained a fonio throughput of approximately 100 kg/h, with a water flowrate of 60 l/min. The residual grit content measured in the fonio after hydrolift treatment was less than 200 ppm.


Figure 28. Hydrolift degritter and the degritting column at Ucodal, Bamako (© P. Thaunay, Cirad)

The operation of the degritter was monitored with the support of IER during May and June 2015, and new degritting trials were conducted in early July 2015 during a Cirad mission (P. Thaunay) to Bamako to fine-tune the prototype hydrolift and incorporate it into Ucodal's production line. The degritter was able to process 450 to 500 kg of fonio per day. In 2016, some modifications were made to the equipment (flowmeter, water filter, etc.) which improved its operation up to 500 to 800 kg per day.

Ucodal is highly satisfied with the equipment which provides a time saving in this degritting operation. Indeed, traditional manual degritting of 800 kg of fonio involves 18 women for a 9-hour working day, whereas degritting 800 kg of fonio with the hydrolift degritter involves only 10 women for a period of 8 hours. The labour freed up in this way could be employed in other, less arduous tasks. The company is considering investing in a second machine to increase its production.

- *"Hydrolift 02" prototype degritter*

The production tests of the hydrolift 01 degritter were able to identify some possibilities for improvement, and led to the design of a second prototype ("hydrolift 02" degritter). This improved prototype was built in Montpellier in late 2015, and then sent to IMAF in Bamako in early 2016 for the manufacture of the chassis and peripherals.

The "hydrolift 02" prototype degritter was then installed on the premises of Danaya Céréales (Bamako) for testing under actual conditions of use. The equipment was monitored in April-May 2016 with the support of an IER technician. Analysis of the monitoring results demonstrates that the machine throughput could reach 130 kg/h, or even 150 kg/h, with a residual grit content considered satisfactory by the operators. Incorporated into the production line at Danaya Céréales, the hydrolift 02 degritter is currently processing 500 kg of fonio per day.

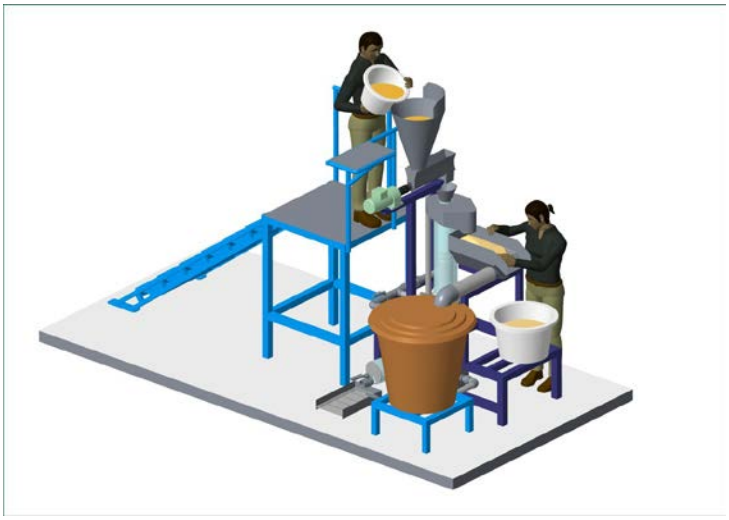



Figure 29. The Hydrolift 02 degritter at Danaya Céréales, Bamako (© P. Thaunay, Cirad)

- *Pilot lot of 2 “hydrolift” degritters*

The first 2 hydrolift prototype degritters, installed at 2 SMEs in Bamako (Mali), were able to achieve very good fonio degritting results under actual conditions of use. So it was decided to produce a pilot lot of 2 hydrolift degritters to equip 2 new fonio processing SMEs, in Burkina Faso and Senegal respectively.

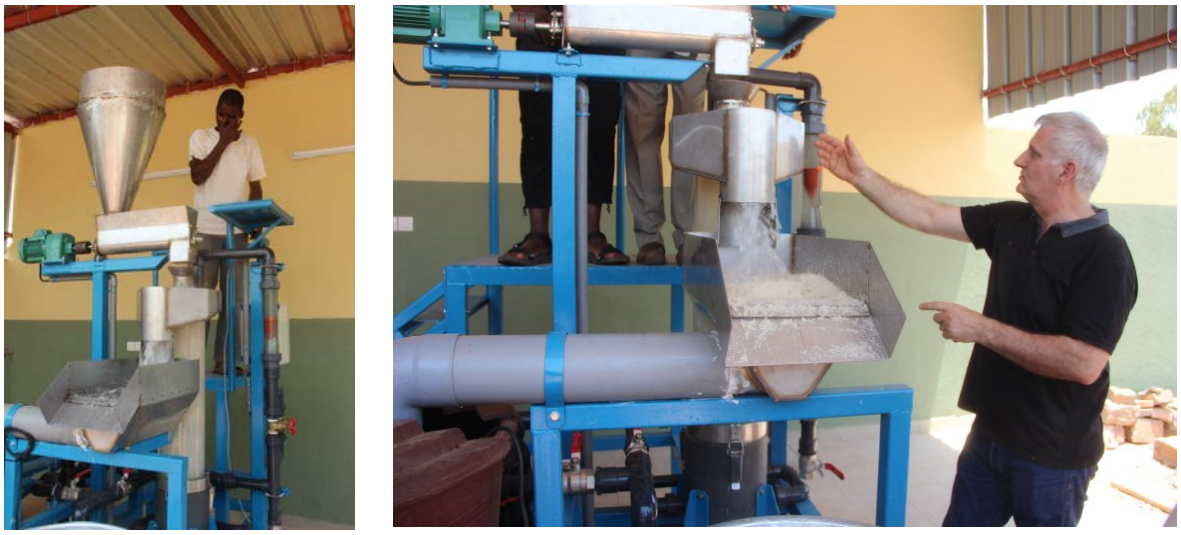


Figure 30. The hydrolift degritter in Bobo Dioulasso (© P. Thaunay, Cirad)

The pilot lot was made in Montpellier, in early 2016. A first hydrolift wash shipped in March 2016 to Soldev (metal manufacturer) in Bobo Dioulasso (Burkina Faso) to make the chassis and peripherals. During a combined Cirad-IRSAT mission (P. Thaunay, A Delpech and V. Bancal for CIRAD; I. Medah and S. Bougma for IRSAT), the first hydrolift was installed, in April 2016, on the premises of the new fonio processing company (UTF), set up by its backer (F.X. Traoré from Bomborokuy) in Bobo Dioulasso. Incorporated into the production line, the equipment provides a throughput of 80 to 100 kg/h.

A second hydrolift was shipped to eastern Senegal in April 2016. This equipment, designed and built in part by Cirad in Montpellier and by Soldev in Bobo Dioulasso, was sent to the Mamba Guirassy technical institute in Kédougou for final assembly, with the support of Cirad. In May 2016, the degritter was installed by Cirad at the "Koba Club" group in Kédougou during a Cirad mission (P. Thaunay, J-P Fleuriot and Ms. V. Bancal).

Under actual conditions of use, the equipment is able to degrit fonio with a throughput of approximately 100 kg/h. Incorporated into the production line of the “Koba Club” group, the hydrolift degritter currently processes 200 kg of fonio per day, but should eventually be able to manage 500 kg per day.

Figure 31. Installation of the hydrolift degritter in Kédougou, eastern Senegal (© V. Bancal, Cirad)

Partial conclusion

The hydrolift degritter meets the specifications that the researchers had set, providing a throughput of around 100 kg/h and a residual grit content in the grain of less than 200 ppm. The private operators are also satisfied with the good performances observed under actual conditions of use. So the mechanisation specialists have validated the equipment for degritting processed fonio. Local companies such as IMAF in Mali and SOLDEV in Burkina Faso were trained to carry out part of the equipment manufacture. Given its high capacity, this equipment is reserved for small companies likely to process at least fifty or so tonnes of fonio per year.

Activity 4. *Adapting and validating dryers for processing SMEs*

✓ *Construction, adaptation and validation of the CSec-T cross-flow dryer*

During the 2000s, Cirad designed and developed the CSec-T cross-flow dryer to improve the drying of granular solid foods such as rolled products (couscous, dégué, arraw, etc.) or processed grains (precooked fonio, germinated sorghum, etc.). In 2007, this equipment was tested by Cirad in Mali in collaboration with IER and the SME "Danaya Céréales" (Marouzé et al., 2008). Under the Aval Fonio project, the aim was to scientifically validate the performances of this dryer and study the possibilities of local manufacture.

- *Principle of the CSec-T cross-flow dryer*

The cross-flow dryer comprises 3 compartments each containing 4 superimposed trays (figure 32). It contains a hot air generator (gas burner) and an electric-motor driven fan. The dryer is made from plywood, and the hot air generator assembly is metallic.

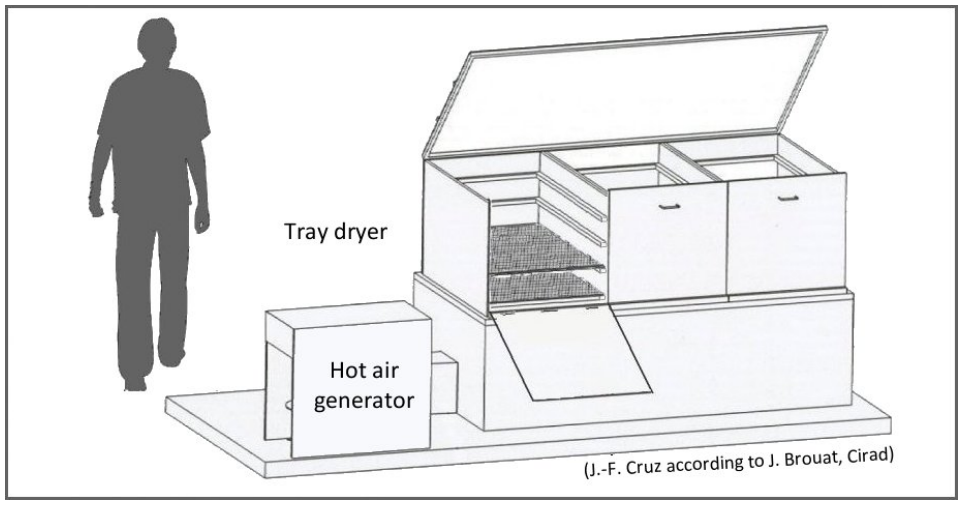


Figure 32. CSec-T dryer (© Cruz et *al*., 2011)

Each compartment is equipped with a door providing access to the various trays. The trays comprise a wooden frame and a galvanised metal mesh supported by stiffeners. Each tray is covered with a net or poplin type fabric (overlapping each side of the grate) to enable the wet product to be deposited and collected when dry.

The hot air driven by the fan is introduced into the dryer via a duct, and then passes through the various trays from bottom to top, thereby drying the product.

The principle of the CSec-T cross-flow dryer is to create a counter-current movement between on the one hand the hot air flow which progresses from bottom to top in each compartment, and on the other hand the product which is gradually moved stepwise from top to bottom from grate position 4 to position 1 (figure 33). In continuous operation, the wet product is spread over a tray placed in the upper position 4 in the dryer. Once the cycle is complete, the dry product is removed from position 1.

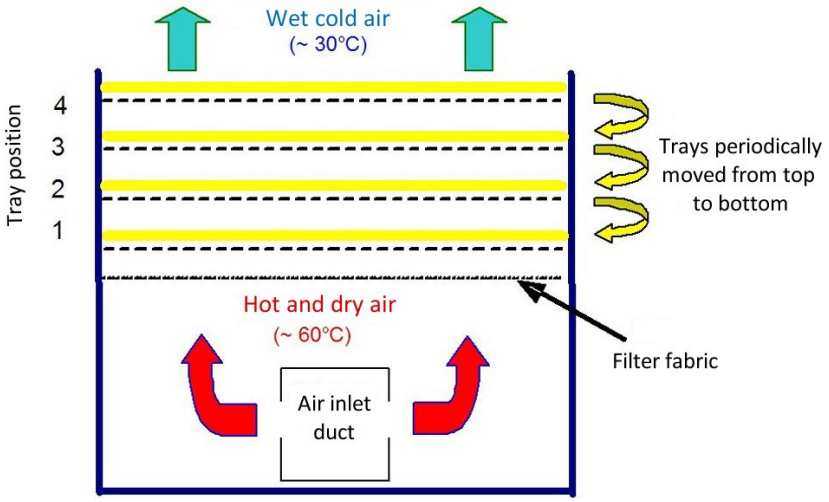


Figure 33. Schematic of the cross-flow dryer (© C. Marouzé, Cirad)

- *Construction, instrumentation and trialling of the CSec-T dryer*

A wooden cross-flow dryer was manufactured in Dakar as per the manufacture plans provided by Cirad, and with the support of the Mechanical Engineering Department of ESP (figure 34).

Figure 34. CSec-T dryer manufactured in Dakar (© ESP)

For the trials, the CSec-T dryer was fitted with the following instrumentation:

- fan outlet temperature measurement sensor,
- temperature measurement sensor under each of the lower grates,
- portable thermo-hygrometer (measuring ambient air and drying columns outlet),
- gas cylinder weighing scale to measure the quantity of gas consumed.
- spring balance (gantry-mounted) for weighing the control grates

The validation tests on the CSec-T dryer were conducted at ESP-UCAD in March 2015 during a Cirad support mission (M. Rivier). These tests involved drying 90 kg of precooked fonio re-moistened to 35% (i.e. 6 kg of wet fonio on each of the 12 dryer grates renewed just once on the upper grates.)

The ambient air temperature, approximately 25°C, was raised to 45°C by circulation over the burner. The product on the lower grates, at the hot air inlet, was dried after 2 hours 45 minutes of operation, and the batch was completely dried after 5 hours 40 minutes. The drying air speed over the grains must not exceed 0.2 m/s to prevent the grains from blowing away after drying.

The quantity of water evaporated during drying was measured at 23.85 kg, and the butane gas consumption was 2.9 kg. Assuming a butane gas LHV of 45,600 kJ/kg, the quantity of energy consumed during the trial was therefore 132,240 kJ. Adjusting this value to the quantity of water evaporated, we obtain a specific thermal consumption of 5545 kJ per kg of evaporated water (i.e. approximately 1540 kWh per tonne of water evaporated).

Under the trial conditions, assuming a latent heat of vaporisation of water of 2500 kJ/kg water evaporated, the energy efficiency of the CSec-T dryer was approximately 45%.

These trials show that the CSec-T dryer was able to obtain a fairly good drying efficiency despite non-optimum conditions of use; since the dryer was reloaded only once with wet product. Under normal conditions of use, with a 100% filled dryer, we could definitely expect an energy value of more than 50 % (specific heat consumption less than 5000 kJ/kg water evaporated), whereas conventionally used natural convection dryers (Atesta dryer) have an energy efficiency of often less than 20 % (specific heat consumption more than 12,500 kJ/kg water evaporated).

Under the trial conditions, the CSec-T dryer was able to dry the precooked fonio from 35% to approximately 10%, with a throughput of 30 to 35 kg/h, and having to adjust the grates every 30 to 40 mins. To improve the dryer's performances (reduce the drying time), it would seem necessary to increase the burner power (up to 8 kW) in order to achieve hot air inlet temperatures of 60 to 65°C.

- *Transfer of the CSec-T dryer to the field in eastern Senegal*

In late 2015, the gas-powered CSec-T cross-flow dryer was transferred to Salémata (eastern Senegal). The dryer was installed for use by a group of 10 associations of women fonio processors.

Figure 35. CSecT dryer in Salémata (© ESP-UCAD)

Figure 36. Operator training (© ESP-UCAD)

After conducting a two-day demonstration in which approximately 150 kg of precooked fonio was dried, the Aval Fonio project supervisor in Senegal (C. M. F. Kébé) trained the women how to use the fonio dryer. The processors, with great enthusiasm and motivation, have continued to use the dryer and pass on the information gathered (quantities dried, gas consumption, etc.) to ESP-UCAD in Dakar.

- *Transfer of the CSec-T dryer to the field in Burkina Faso*

As planned at the Aval Fonio workshop in Dakar in June 2015, a CSec-T cross-flow dryer was built in Bobo Dioulasso in November 2015 by SOLDEV (M. Ouattara) with the supervision of a Cirad technician (A. Delpech) and under the aegis of the supervisors of WP4 "Innovation process in small fonio processing plants" (T. Ferré and I. Medah). Then a second dryer was manufactured in March 2016.

Figure 37. Training in how to use the *CSecT* dryers in Bobo Dioulasso, Burkina Faso (© T. Ferré, Cirad)

A training session on how to use CSec-T dryers was conducted in Bobo Dioulasso for fifteen or so fonio processors from western Burkina Faso and Ouagadougou (figure 37). It was held in March 2016, at IRSAT in Bobo Dioulasso, led by researchers and technicians from Cirad (T. Ferré and A. Delpech), IRSAT (I. Medah), and ESP-UCAD (A. Diallo), and in collaboration with the NGO "Afrique verte Burkina – Aprossa" (Ms. M. L. Dipama).

A CSec-T dryer user manual was drawn up to help train the operators:

> *Cruz J-F., Rivier M., Ferré T., Delpech A., Diallo A., Kebe C.M.F. 2016. CSec-T dryer User Manual. Aval Fonio project, deliverable no.15. Cirad. Montpellier. 7 p.*

During the training session, an operating trial was carried out under the following conditions:

The CSecT dryer was loaded with 55 kg of wet precooked whitened fonio (moisture approximately 35%) distributed on the grates as shown in figure 38, specifically: 5 kg of wet fonio on each of the 9 lower grates, and 3.3 to 3.4 kg on the upper grates.

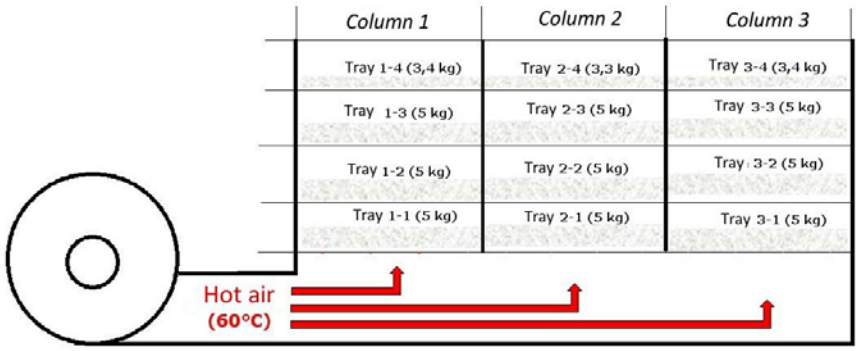


Figure 38. CSecT dryer load diagram (© J-F Cruz, Cirad)

The hot air temperature at the fan outlet was kept at 60°C. The inlet temperature to which the product was exposed was observed as homogeneous on all 3 dryer compartments.

One hour after the dryer was started, the bottom level grates were weighed to assess the progress of drying. The readings were: C1.1: 3.5 kg; C1.2: 3.4 kg; C1.3: 3.5 kg. These various values show that after one hour's drying, the fonio on the bottom level grates is dry. We found that it was actually slightly overdried, since the final mass of 5 kg of 35 % wet fonio dried to 10 % should be 3.61 kg (unless the initial moisture of the product was more than 35 %). After switching the racks, the entire load of fonio (55 kg) was dried in 2 hours 20 mins. Weighing the gas cylinder gave the quantity of gas consumed during the trial: 1.5 kg of gas in 2 hours 20 mins.

With a butane gas lower heating value (LHV) of 45,600 kJ/kg, the burner power is calculated as follows: heat power emitted: 45,600 x 1.5 = 68,400 kJ or 19 kWh i.e. for a drying time of 2 hours 20 mins, a burner power of: 19 / 2.33 = 8.1 kW

During the trial, the total quantity of water extracted from the fonio by drying was 16.1 kg. The quantity of input energy per kg water evaporated is therefore: 68,400/16.1 = 4248 kJ/kg. With a water vaporisation heat of 2500 kJ per kg water evaporated, the theoretical consumption of a dryer (100% efficiency) should have been: 2500 x 16.1 = 40,250 kJ. Yet the consumption was 68,400 kJ i.e. the energy efficiency of the CSecT dryer was 40,250 / 68,400 = 59 %.

This efficiency is better than the 45% observed during the tests conducted in Dakar in March 2015 (see page 22), since the hot air inlet temperature was maintained at 60 °C, whereas it was only 45°C in the Dakar trial. This efficiency of 59 %, excellent in itself, could be further improved by increasing the quantity of fonio to be dried, i.e. by adding wet grates when the bottom grates are dry and have been emptied. By way of comparison, we should recall that the efficiency levels usually observed with conventional Atesta grate dryers are only 20 % at best.

The 2 CSec-T dryers were then installed on the premises of 2 fonio processing SMEs for monitoring under actual conditions of use. These 2 SMEs, "Tout Super" in Toussiana and EOBA in Ouagadougou, were selected because they have always closely collaborated with the researchers working to improve the fonio industry in West Africa.

Partial conclusion

The CSecT dryer meets the specifications that the researchers had set, by ensuring a load capacity of approximately 100 kg and a throughput of 30 to 35 kg/h for drying wet processed fonio (white or precooked) from 35% to 10%. Using a hot air inlet temperature of around 60 °C (burner power 8 kW), it is able to achieve an energy efficiency of around 60%, distinctly higher than the 20 % efficiency obtained with artisanal dryers based on natural convection (Atesta). The private operators which had the opportunity to use the CSec-T dryers are satisfied with the good performances observed under actual conditions of use. So the mechanisation specialists have validated this equipment for drying processed fonio (whitened and/or precooked). A local company, SOLDEV in Burkina Faso, has been trained to manufacture the equipment.

✓ ***Design, adaptation and validation of the CSec-S "greenhouse" dryer***

- *Principle of the CSec-S "greenhouse" dryer*

During the 2000s, a *CSec-S "greenhouse"* dryer was designed by Cirad and tested in Mali (figure 39). Under the Aval Fonio project, the aim was to scientifically validate the performances of this sort of dryer and investigate the possibilities for local development.

The greenhouse dryer represents an alternative to direct solar drying. The product is dried by direct exposure of the product to solar radiation and via the greenhouse effect (higher temperature inside the greenhouse than outside). The objective is to carry out drying at a relatively low temperature using solar radiation as a heat source.

The greenhouse dryer was designed:

- on the one hand, to protect the products to be dried (fonio or other products) from the weather, birds and airborne dust,
- on the other hand, reduce handling of the product. By contrast to natural sun drying, there is no need to bring in the products when the rains arrive or in the evening if the products have been put out to dry during the day.

The greenhouse dryer simply comprises a metal tube structure supporting a plastic film. The structure rests on a masonry slab. The front gable has a door and aeration windows cut into it. The rear gable of the dryer is equipped with one or more axial fans which renew the dryer air, and by reducing the temperature, enable the operators to access the dryer during the day to move the product around.

Figure 39. The first *CSec-S* "greenhouse" dryer installed by Cirad in Mali in 2006 (© J-F Cruz, Cirad)

The greenhouse dryer is equipped with trays covered with a fabric (net or poplin), on which the wet fonio is spread in a thin layer. It is normally possible to dry 300 kg to 400 kg of precooked fonio with this model of dryer.

- *Construction and instrumentation of an experimental CSec-S dryer in Senegal*

Based on the specifications drawn up in 2013 with Cirad, two *CSec-S* "greenhouse" dryers were ordered from FilClair (Marseille, France) in 2014. This equipment was delivered to Senegal and one of the *CSec-S* "greenhouse" dryers was installed on the ESP-UCAD site in Dakar by the Mechanical Engineering department in 2014 (figure 40).

The greenhouse dryer comprises an agricultural greenhouse with a surface area of approximately 90 m² (14 x 6.4 m) and a volume of 200 m^3 (figure 41).

Figure 40. View of the CSec-S dryer (© T. Ferré, Cirad)

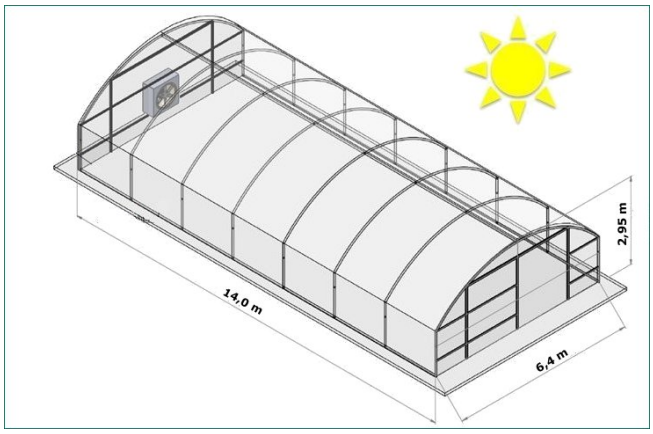


Figure 41. Diagram of the "greenhouse" dryer (© ESP)

The *CSec-S* "greenhouse" dryer is equipped with 8 rectangular trays suspended from the greenhouse frame arches. The trays are made from wood with a wire netting base covered with a net or poplin type fabric to hold the fonio spread in a thin layer (figure 42). The dimensions of the trays are 2.5 m x 1.5 m (with separation into 4 zones representing a useful surface area of 3.5 m²).

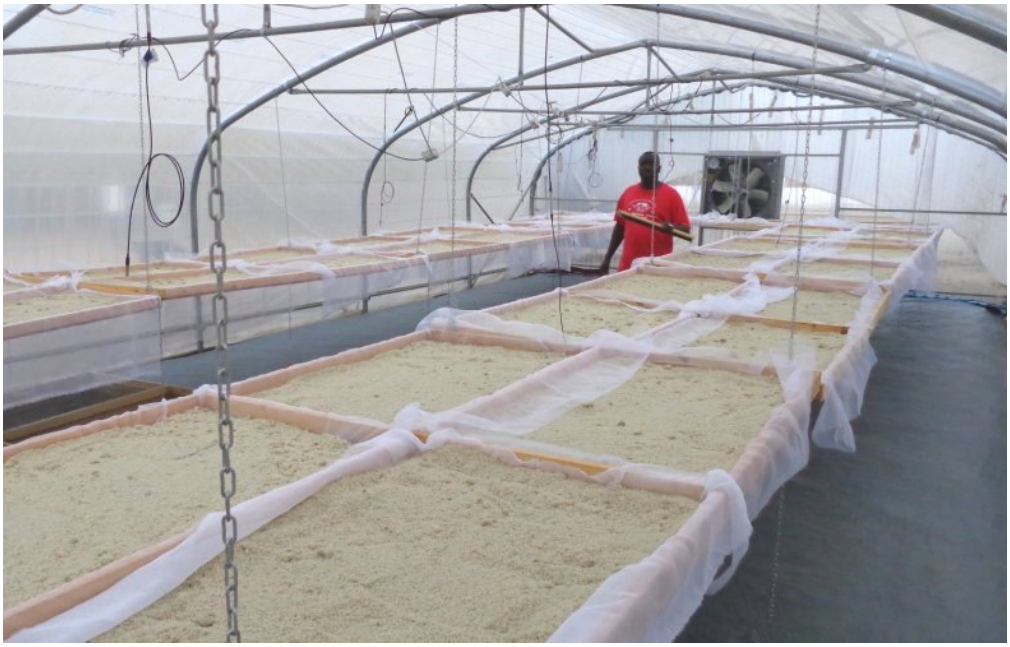


Figure 42. Thin layer of fonio on the drying trays (© M. Rivier, Cirad)

The greenhouse instrumentation (thermometer sensors, humidity sensors, acquisition centres, etc.) were installed during a support mission by Sirea (L. Biau) carried out in January 2015.

The greenhouse dryer is equipped with the following instrumentation:

- thirteen thermometers-humidity sensors distributed throughout the greenhouse,
- a pyranometer for measuring solar radiation, mounted on a post outside the greenhouse,
- an acquisition centre for the data read by the sensors and pyranometer.

- *Experimental CSec-S dryer validation trials in Senegal*

Two preliminary validation trials on the experimental CSec-S dryer were conducted at ESP-UCAD in March 2015 during the Cirad support mission[3]. These trials were conducted on model product (rags soaked in water, and then precooked fonio re-moistened to 30 % on 2 of the 8 grates).

The trial results show that during drying, the quantity of water removed was slightly more than 1 kg/m² tray surface. Weighing the controls also revealed very high drying homogeneity for the various trays.

The temperatures and humidities in the greenhouse were read throughout the trial, and their changes are set out in figure 43.

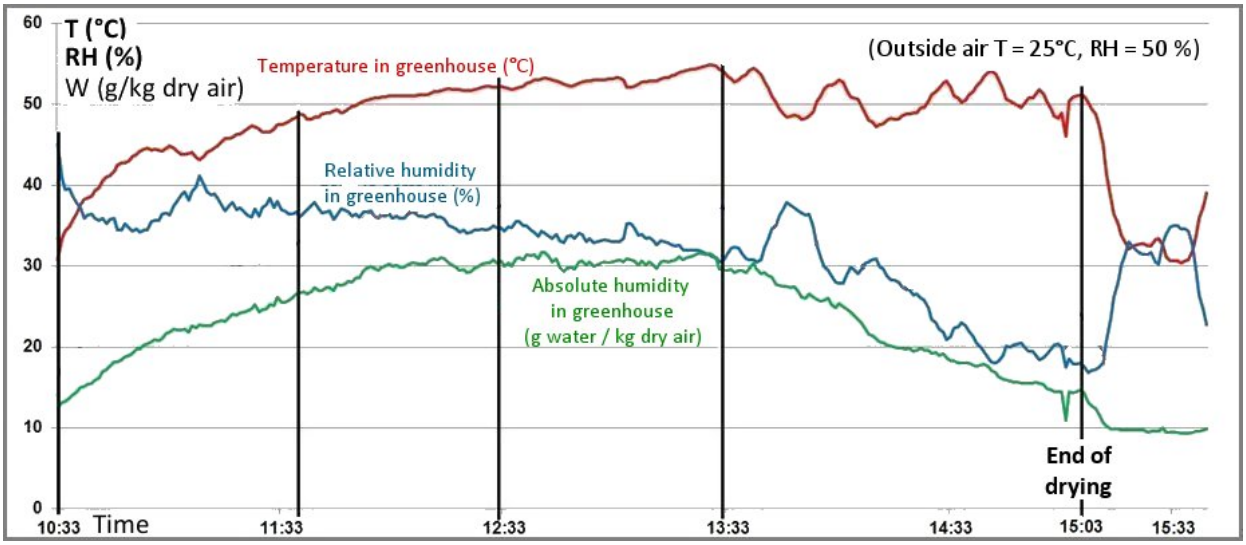


Figure 43. Monitoring of air temperature and humidity in the greenhouse during a trial (© M. Rivier, Cirad)

We can observe that the temperature in the greenhouse reached a value of more than 50°C (with a maximum of 55°C) while the average outside air temperature was 25°C. The absolute humidity of the air in the greenhouse went from 12 g water / kg air at the start of drying to a value of 30 g water / kg air during drying, before then decreasing at the end of drying. We can question this reduction in absolute humidity of the air in the greenhouse when drying was complete, which could be due to disruption by air entering, or stratification of layers of more or less wet air in the greenhouse.

A third, full-scale, drying trial was conducted in June 2015 during the Aval Fonio meeting in Dakar. It involved drying 315 kg of wet precooked fonio (in theory 35 %) spread in a thin layer over 10 grates (or 35 m²), as shown in figure 44. The grates were loaded on 10 June at 20:00.

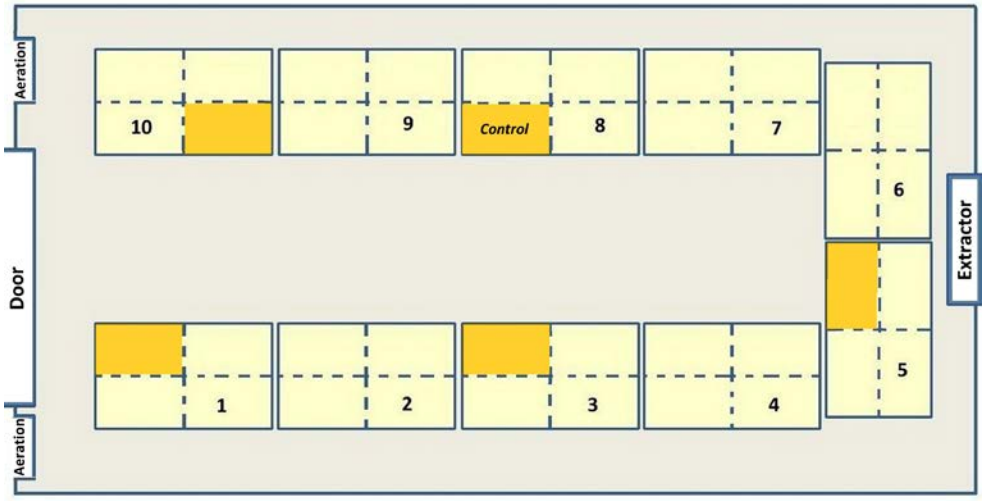


Figure 44. Layout diagram of the drying trays in the CSec-S dryer (© M. Rivier, Cirad)

[3] Rivier M. 2015. Validation tests for the cross-flow dryer (CSec-T) and "greenhouse" dryer (CSec-S). Aval Fonio project. Cirad, Montpellier, France. 20 p.

The drying trial was ended on 11 June at 16:30, i.e. after the fonio had been in the greenhouse for 20 hours 30 minutes, with approximately 9 h of actual sun exposure. Periodic weighing of control grates confirmed the good drying homogeneity on the various grates.

The quantity of fonio recovered was weighed at 210 kg of dry fonio. So 105 kg of water was eliminated during the drying process. If we assume that the dried fonio has a moisture content of 10 % (i.e. 189 kg dry matter and 21 kg water), it means that the wet precooked fonio contained 189 kg dry matter and 126 kg water, and so that its initial moisture was 40 % (precooking operation may be poorly controlled?). Or, if we start from a higher initial moisture (e.g. 37 %), it means that the fonio was overdried, to a moisture of 5.5 %.

Figure 45. Fonio greenhouse drying trial in Dakar (© J-F Cruz, Cirad)

- *Transfer of the CSec-S dryer to the field in Senegal*

A CSec-S “greenhouse” dryer was transferred to the Koba Club group in Kédougou, eastern Senegal, at the end of 2015. In October 2015, a mission ESP-UCAD mission was conducted to support the civil engineering work carried out by CSBAT led by its Technical Director (D. Gouba). Then a “greenhouse” dryer was installed in December 2015 by an ESP-UCAD mission (C.M.F. Kébé, A. Anne, A. Diallo...) and CSBAT (D. Gouba).

Figure 46. The CSec-S greenhouse dryer at the *Koba Club* group in Kédougou, Senegal (© A. Diallo, ESP/UCAD)

Initial operating trials were able to dry approximately 250 kg of precooked fonio.

Then the drying (using 8 trays) was monitored from 7 to 24 January 2016 by the Koba Club group, which thus provided the following data to the Aval Fonio project (table 4)

Table 4. Fonio drying monitoring in the CSec-S dryer at the Koba Club group.

N°	In date	Time	Wet fonio (kg)	Out date	Out time	Drying time	Sun exposure	Dry fonio (kg)	Quantity water extracted (kg)
1	7/01/2016	19h00	108	8/01/2016	13h30	18h30	6h15	77	31
2	8/01/2016	18h05	175	9/01/2016	15h10	21h05	7h55	126	49
3	9/01/2016	18h40	150	10/01/2016	15h00	20h20	7h45	108	42
4	11/01/2016	17h50	185	12/01/2016	14h40	20h40	7h25	130	55
5	12/01/2016	18h20	155	13/01/2016	15h30	21h10	8h15	102	53
6	13/01/2016	18h20	166	14/01/2016	15h10	20h50	7h55	108	58
7	14/01/2016	18h10	182	15/01/2016	14h20	20h10	7h05	124	58
8	15/01/2016	19h00	168	16/01/2016	14h00	19h00	6h45	119	49
9	16/01/2016	19h15	119	17/01/2016	15h55	20h40	8h40	87	32
10	18/01/2016	18h30	157	19/01/2016	14h30	20h00	7h15	110	47
11	19/01/2016	19h30	182	20/01/2016	14h15	18h45	7h00	129	53
12	20/01/2016	18h35	189	21/01/2016	16h20	21h45	9h05	132	57
13	21/01/2016	18h30	123	22/01/2016	14h10	19h40	6h55	96	27
14	23/01/2016	19h10	153	24/01/2016	15h30	20h20	8h15	107	46
15	24/01/2016	18h30	267	25/01/2016	17h30	23h00	10h15	192	75

Taking the data from the table, and assuming that the end moisture of the dried fonio is around 10 %, we find by calculation that the initial moisture of the precooked fonio placed in the greenhouse is on average definitely closer to 35 % than 30 %! (Rows 1, 2, 3, 4, 7, 8, 9, 10, 11, 12, 14 and 15).

For rows 5 and 6 (drying on 12 and 13 January), the initial moisture of the product definitely had to be around 40 % or more, whereas for row 13 (drying on 21 January), the initial moisture was definitely closer to 30 %.

We can observe (row 15) that the operator was able to dry 267 kg of wet fonio (from 35% to 10 %) in a drying time of 23 h, but above all with a sun exposure of 10h15. This drying operation corresponds to a load of more than 33 kg of wet fonio per grate (267 kg divided between 8 grates). This load is excessive, since the load per grate should not exceed 30 kg (which corresponds to approximately 8.5 kg/m²).

Finally, we can note that the Koba Club group loaded the dryer with wet fonio in the evening after 18:00. This practice is not ideal, since the dryer is in this way filled with a large mass of wet product at a time of day when solar radiation is negligible. Thereafter a period of fifteen hours (night and early morning) will pass, during which the temperature in the greenhouse drops, and may cause high risks of condensation (and possibly fermentation) before the solar radiation regains its efficiency (around 10 a.m.). So the group's work schedule will need to be modified so that the dryer is loaded in the morning between 11:00 and 12:00, in order to take full advantage of the solar radiation.

During the experimental trials conducted in Dakar in March 2015, the solar radiation on the greenhouse (expressed in W/m²) was read using a pyranometer. The curve shown in figure shows that the solar radiation is most efficient (> 600 W/m²) between 10:00 and 16:00, with a maximum of close to 1000 W/m² at around 13:00.

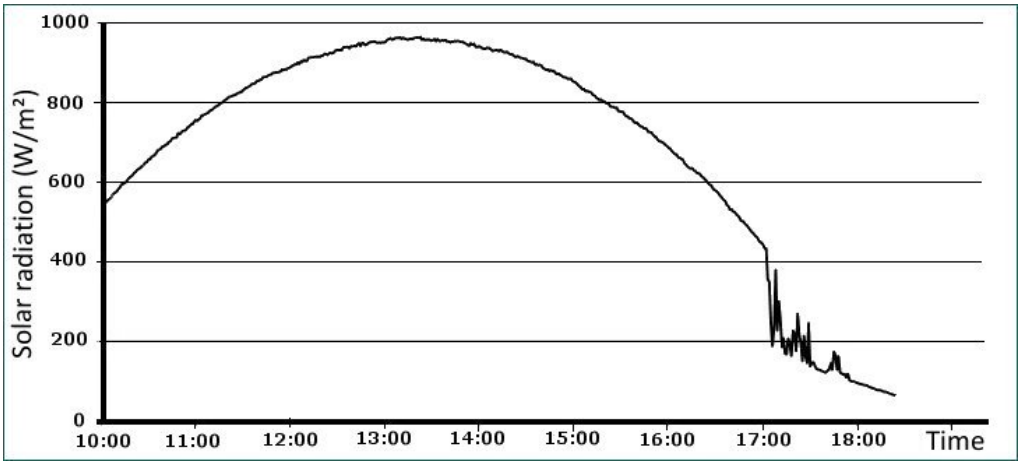


Figure 47. Solar radiation on the greenhouse over the course of a day (© M. Rivier, Cirad)

With an outside temperature of 30 °C, the temperature in the greenhouse may reach 55 to 60 °C. This temperature can be rapidly lowered by activating the extractor to enable the operators, if need be, to load or empty the dryer under milder temperature conditions.

Partial conclusion

The 90 m² *CSec-S* greenhouse dryer, equipped with 10 trays or more, meets the specifications that the researchers had set, ensuring a load capacity of approximately 300 to 350 kg to dry wet processed fonio (white or precooked) from 35% to 10% in 24 h. The private operators which had the opportunity to use the *CSec-S* dryers are satisfied with the good performances observed under actual field conditions. To ensure more rational use of the greenhouse dryer, we must recommend loading the dryer in the late morning, in order to fully harness the solar radiation to ensure efficient drying and rapid stabilisation of the fonio. So the mechanisation specialists have validated this equipment for drying processed fonio (whitened and/or precooked). Distribution of this type of dryer should be promoted among agribusiness processing units, since it is versatile and should be usable on various types of agricultural products. The target SMEs must however have a sufficiently large and clear space to enable its installation.

Note: Installing a "greenhouse" dryer in the field in Guinea.

At the annual meeting in Dakar in February 2016, IRAG expressed the desire to harness the results of the Aval Fonio project in terms of drying for the benefit of some operators in Guinea. The coordinators suggested the idea of installing a small greenhouse dryer in the rural community of Pilimini (Koubia prefecture). In this village in Fouta Djalon, a women's group wanted to develop its fonio processing activity to boost the value of this cereal by producing precooked fonio (a processed form of fonio which is rare in Guinea). The group is supported by the Franco-Guinean NGO ADESAG, which works for the development of socially responsible enterprise in Guinea, and which has already equipped the group with a GMBF huller-whitener.

Initially, as the quantities processed by the women processors were still relatively low (a few tens of kg), it was agreed that the Filclair brand greenhouse dryer was oversized, and that a dryer of only around 20 m² should be installed.

A Tonneau brand greenhouse ("5ème saison" line) was chosen, with the following characteristics: length: 4.5 m, width: 5 m, height: 2.37 m. The greenhouse comprises a galvanised steel frame with a transparent reinforced PVC covering. Given its small size, the greenhouse is not equipped with an air extractor, but simply with a door on each of the gables, to facilitate the air current to enable natural aeration.

In Pilimini, the greenhouse was installed on a slab laid by the beneficiaries.


Figure 48. Greenhouse dryer (Tonneau brand) in Pilimini, Guinea (© H. Baldé, Adesag)

2.2.4. **WP4: The innovation process in small fonio processing plants**

WP4 is aimed at firstly generating knowledge about the innovation processes involving small fonio processing companies. It is also aimed at developing a co-design system of fonio processing and stabilisation technologies (washing, degritting and drying), bringing in alongside the WP3 researchers the field players (equipment manufacturers, potential users, support structures, etc.) who are also stakeholders in the innovation process.

Activity 5.1. *Identifying the processing innovation system players*

This activity was carried out mainly during 2013 and 2014.

In Burkina Faso, two studies were conducted on equipment manufacturers in the cities of Ouagadougou and Bobo Dioulasso. This work was used to characterise these players, but also to identify potential partners capable of contributing to the development and dissemination of fonio processing equipment. The researchers made an initial selection of four companies: NTELFAC (formerly SGGI), SRC, REMICO and Agri-équipement.

This selection was made mainly on the basis of five criteria: the nature and complexity of producing the equipment already manufactured, qualification of the company manager and their personnel, the equipment and machine tools available in the production unit, experience of partnerships and desire to collaborate with research. At the project annual meeting held in Burkina Faso in January 2015, a meeting was organised with the companies REMICO and Agri-Equipement, which are IRSAT partners in manufacturing GMBF hullers and screening cleaners.

Figure 49. Visit to the company Agri-Equipement in Ouagadougou (© J-F Cruz, Cirad)

In Mali, a survey of the fonio processing units in Bamako was conducted district by district. The results reveal the existence of at least 71 fonio processing companies in Bamako (figure 50). This is an activity practically exclusively carried out by women, and the few men in these companies are assigned to operating equipment (hullers, mills and dryers). In addition to their fonio production, these companies generally manufacture a wide range of cereal products or condiments.

More than a thousand people are directly employed, on a temporary or permanent basis, by these processing units. There is a dual trend in this sector of activity: both a proliferation in the number of companies, with more than 80% established in the 2000s, but also the expansion of some of them.

We were able to identify 3 processing companies as the sector leaders: UCODAL, Danaya Céréales and Dado Production, which sell their production on both the national and export markets, in Europe and North America. There is a very high investment level in the business. They use premises dedicated entirely to processing products, and have introduced a host of equipment in their production process (rotary screens, GMBF hullers, gas dryers, mills, etc.).

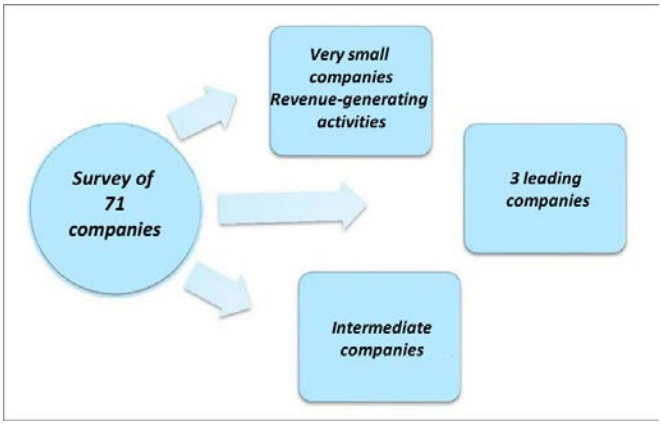


Figure 50. Fonio processing units in Bamako (© T. Ferré, Cirad)

Activity 5.2. *Studying the relations between the components of the innovation system*

Under this activity, the planned starting point of the analysis of the components of the innovation system and their interrelations was the observations and surveys, as well as technical changes (specific equipment) which have occurred in fonio processing techniques. The particular focus was on the GMBF huller, which was designed and then introduced and disseminated in 2002 under the first fonio project.

✓ ***Innovation impact study of the "GMBF huller" in Burkina Faso and Mali***

Impact assessment approach

Our analysis is based on the ImpresS methodology developed by Cirad. In operational terms, the conceptual framework for the innovation analysis and the contribution of research to the impact should:

- produce a narrative of the fonio huller innovation leading to the impacts,
- build an initial hypothesis of the impact pathway, starting from the desired change led by research,
- define and refine the hypotheses with the players, better specifying the innovation narrative, the pathway and nature of the impacts (1st participatory workshop),
- systematically document the outputs and outcomes generated,
- characterise and quantify the level 1 impacts (in terms of the players interacting with research and/or its partners) by a multi-criteria method based on surveys and/or focus groups,
- characterise and quantify certain level 2 impacts (change of scale or spillover) by a variety of methods (collecting secondary data in particular),
- Validate all the results with the players (2nd participatory workshop),
- Finalise the study (innovation narrative, impact pathway, quantification of impacts).

The impact pathway can be represented by the diagram below:

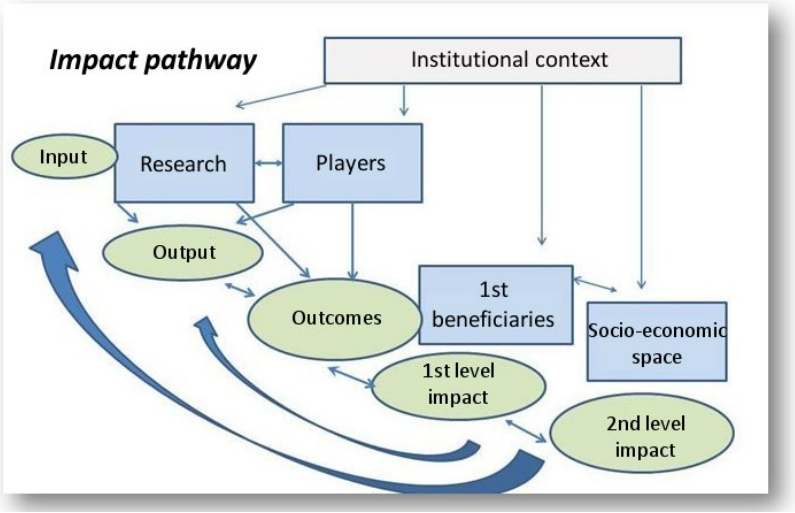


Figure 51. Impact pathway diagram (© Cirad Impress)

Impact assessment study

The study was conducted by Cirad with the collaboration of IRSAT and the support of an ISTOM intern (M. Chtioui) assigned to Cirad from April to August 2015, and then to the field in Burkina Faso from April to mid-June 2015. For the field surveys in Burkina Faso, Cirad and IRSAT requested the collaboration of the NGO "Afrique Verte" (Aprossa). In Mali, they collaborated with the NGO "Afrique Verte" (Amassa) and IER (Ms. F. Guindo).

To kick off the impact assessment study, a Cirad-IRSAT joint mission (T. Ferré & M. Chtioui for Cirad, and I. Medah for IRSAT) was conducted in western Burkina Faso (Boucle du Mouhoun) in May 2015. This mission provided the opportunity to meet a number of industry operators:

- Collective interviews with 2 producers' groups from Bomborokuy: "Varossé" (23 producers) and "Zoumé" (14 producers)
- Collective interviews with 3 women processors' groups from Bomborokuy: "Passé" association (55 women), "Brayorona" association (34 women) and the Benkadi group.
- Individual interviews with companies which have installed a GMBF huller-whitener / Identifying the dynamics in progress / Evolution of business (in Bomborokuy, Nouna and Djibasso)
- Meeting with Mr. François Ouedraogo (State Contract/35 IMAF hullers for Burkina).
- Meeting with "Afrique Verte" (Aprossa) and IRD project (International Relief & Development.)

Main information collected in Burkina Faso

For the producers and women processors, the main changes observed over recent years are:

- Change in the status of fonio: from a lean-season cereal to a commercial product
- More than 2/3 of production goes onto the market,
- General increase in total surface areas sown with fonio / and per producer,
- Increase in fonio sale price,
- Dynamic in progress thanks to: threshers and hullers available on a contract basis,
- More than half of production is processed by hullers,
- Service price: 1000 FCFA / tine (approx. 15 kg) i.e. 67 FCFA/kg (or €0.1/kg).

The main constraints remain the lack of threshers and hullers.

A company from Bomborokuy (F.X. Traoré), equipped with 3 GMBF hullers and 2 threshers ("Bamba", manufactured in Mali), has been operating in production and contracting since 2010. In 2014-2015 it handled 50 tonnes of whitened fonio. It sells mainly to Mali, though it is faced with strong competition on this market.

Figure 52. GMBF hullers in Bomborokuy (© T. Ferré, Cirad)

The company has now set up in Bobo Dioulasso to create a fonio processing unit (UTF) covering the process all the way to the finished and packaged product (packaging from Ghana). It welcomed the installation of the hydrolift degritter (see § 2.2.3), and invested in a CSec-T cross-flow dryer.

A company from Nouna (Gaia Bio Solidaire) has produced parboiled semi-wholegrain organic fonio for export since the 2000s. The company is certified by Ecocert and supported by the NGO "Orange Bleue Afrique". In 2014-2015, it produced 30 tonnes, 26 of which were exported since wholegrain fonio is still difficult to sell on the local or regional market. It supervises 9 groups representing nearly 400 organic producers, and purchases the raw material at 175 FCFA/kg (instead of 150 FCFA/kg which is the price usually charged). The 30 tonnes over the 2014-2015 campaign was purchased from 50 producers.

The company is equipped with a new GMBF huller (April 2015) and an older, worn huller with a throughput of just 65 kg/h. It is also equipped with a rotary screen. The originality of this company lies in producing parboiled semi-wholegrain fonio. It is paddy fonio which is parboiled (by steaming). The processing scheme comprises the following operations: cleaning (screening), washing-degritting, parboiling, drying and then hulling (with partial whitening). The number of degritting phases applied to the paddy fonio is limited to 4. The unit can process 560 kg of fonio per day.

Finally, a company from Djibasso (P. Koeta) is equipped with an engine-driven GMBF huller and a rotary screen, enabling it to act as a service provider.

Figure 53. GMBF huller at Gaia, Nouna (© T. Ferré, Cirad)

Main findings in Burkina Faso

The fonio hullers currently installed by the companies are GMBF hullers manufactured by IMAF in Mali. Although this huller was developed in the early 2000s, there are still no manufacturers able to provide it in Burkina Faso.

At the project annual meeting in Ouagadougou of January 2015, the researchers had the opportunity to meet the company REMICO from Ouagadougou, which was manufacturing some machines, but other manufacturers were also identified, as shown by table 5 below.

Table 5. Some equipment manufacturers identified in Burkina Faso

Company	Representative	Associated system	Location	Research support
ACEMG	Hermann Ouedraogo	US IRD project	Bobo Dioulasso	Identified by IRSAT for training in building a variety of fonio and sesame equipment
Ets Godijo et frères	Omar Godjio	US IRD project	Banfora	
AgriEquipements	Alassane Ganou	US IRD project	Ouagadougou	
Remico	Yves Zongo	US IRD project	Ouagadougou	
Yétéli Constructions	Jean Kamaté	US IRD project	Nouna	
AMB	Joseph Pogogné	IRSAT subcontracting	Ouagadougou	Parts manufacturing
STAB	Sory Sanogo	CFC fonio project	Bobo Dioulasso	CFC fonio project (whitener cone, but abandoned)
AGCM	Karim Guira	IRSAT subcontracting	Bobo Dioulasso	Produced jigs based on GMBF from Ms. Traoré
SOAF	Mamadi Camara	Independent	Bobo Dioulasso	Says that the market is insufficient

In Burkina Faso, the lack of clearly accredited fonio equipment manufacturers is still forcing processing companies to procure machinery from Mali (IMAF); which may cause various difficulties with equipment maintenance.

The IRD project [International Relief & Development (2013-2015)] was conducted in the fonio post-harvest segment in collaboration with IRSAT and "Afrique Verte". It was planned to train five equipment manufacturers in manufacturing the GMBF huller (see table no.5). This may seem excessive, since it would be more realistic to select at most 2 equipment manufacturers (1 in Ouagadougou and 1 in the Bobo Dioulasso region), which could work in direct collaboration with IMAF in Bamako.

Main information collected in Mali

In Mali, the system of assessing the impacts of the fonio huller innovation was based on an identical approach. The Malian Association for Food Security and Sovereignty (AMASSA - Afrique Verte Mali) contributed actively to implementing the impact assessment approach proposed by Cirad. In particular it was able to hold the participatory workshops with the fonio industry players, and conduct certain field surveys with the support of Ms. Fanta Guindo (IER). The study made it possible to develop an impact pathway which helps identify the contribution of research to the process. It also helps identify the outputs of the research or research-players collaboration, the outcomes, the level 1 impacts affecting the players (equipment manufacturers, women processors-testers) interacting directly with research, and the level 2 impacts which involve a larger number of players (e.g. producers).

The impacts were characterised by descriptors which are meaningful for the players. These descriptors were collected during individual or group interviews, first of all during the innovation narrative, and then at a participatory workshop held on 22 July 2015 in Bamako with the fonio industry players. These descriptors were then converted into a limited number of indicators, which may be quantifiable or assessed qualitatively, and which indicate an evolution between a reference situation and the execution period of the study. Finally, the results of the analysis were validated at a final workshop with the players, which was held on 24 June 2016 in Bamako.

Main findings in Mali

The main findings emerging from this analysis in terms of the companies are as follows:

- The "*GMBF fonio huller*" innovation had a considerable impact on the equipment manufacturer IMAF and on the women processors who participated in its development. IMAF sold nearly 112 fonio hullers. The women processors saw a big increase in production volumes. In the space of 15 years, the annual production of the 3 main Malian companies went from a few tonnes to more than one hundred tonnes, creating forty or so jobs. In late 2015, *Danaya Céréales* opened a new production unit (figure 54) in the industrial zone of Dialakorobougou, situated on the outskirts of Bamako. Its objective is to process 4 tonnes of fonio per day in 2018, to better satisfy the growing demands on the domestic and export markets.

Figure 54. Danaya Céréales in Dialakorobougou (© P. Thaunay, Cirad)

- The women processors who are not equipped with a GMBF huller do however have access to this equipment, thanks to the emergence of primary processing companies which sell hulled and whitened fonio, or thanks to service providers. This is the case in Bamako, but also in the provinces. Thus in the region of Ségou, the company UTC based in San, which started operating with fonio in 2009, now processes nearly 1200 tonnes of fonio per year. It owns 6 hullers and employs 22 permanent and 30 temporary staff.

- In Bamako, 80 % of fonio processing companies were created over the period 2000-2015.

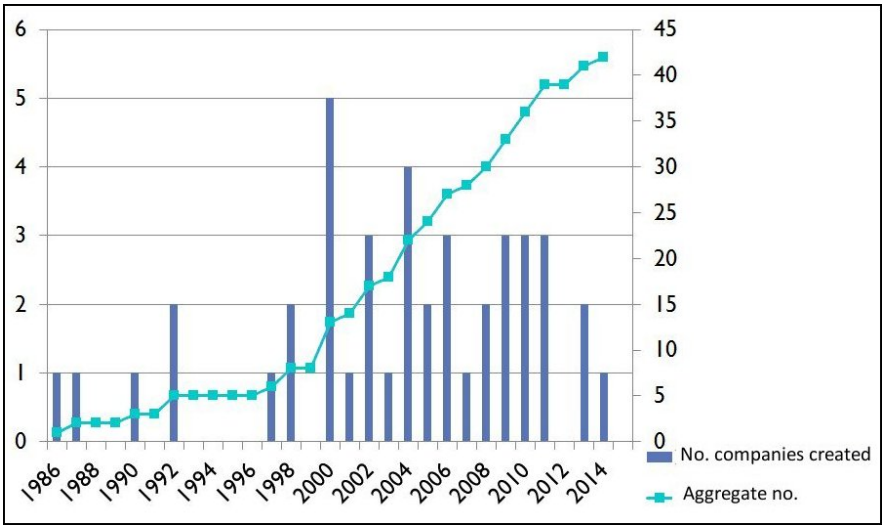


Figure 55. Evolution of creation of fonio processing companies in Bamako (Mali)

- In rural zones, the installation of hulling service workshops has helped maintain or even expand fonio cultivation**.** Thus, 80% of producers surveyed in the villages equipped with or close to a huller state that their fonio cultivated surface areas have increased since the installation of the machine. All the producers surveyed consider that there has been an increase in the number of fonio producers in their village since the arrival of the huller.
- All producers marketing their fonio consider that their revenue has increased thanks to fonio sales: 50% rate this increase as very large, 40 % as medium, and 10% as minor.
- All fonio producers surveyed state that their dietary situation has improved thanks to the maintenance or expansion of fonio cultivation. The producers say that they retain all or some of their fonio harvest for family consumption. Since the fonio harvest comes before that of the other cereals, it therefore provides food during the lean season. The majority of producers surveyed also underline the usefulness of fonio in enabling them to diversify their diet and offering the option of preparing various types of dishes.
- The mechanisation of hulling is contributing to improving the living conditions of rural households. In the villages surveyed, all the women emphasise that the huller has released them from a task which they deem highly arduous. Women and men are unanimous in saying that the huller has eased the workload, saving fonio from a steady decline. They all say that mechanical hulling has helped reduce family tensions.

✓ *Lessons on the innovation approach*

Besides the results in terms of impacts, the case study relating to the GMBF huller has helped enrich the debate on the management of innovation projects and on the conditions and mechanisms promoting the appropriation of research results by agribusiness companies. The study contributes to answering the questions raised on: how to improve the technological innovation approaches implemented by the researchers? How to support SME innovation in agribusiness?

This study reveals key factors, necessary conditions which have made a major contribution to the dissemination of the research results and to innovation. Today, the long experience of the researchers in equipment design clearly shows that knowledge sharing with the equipment manufacturers is not automatic; scientific evidence alone does not necessarily lead to changes and innovations.

Certain conditions were essential for the equipment manufacturers and women processors to appropriate the research results. The operating methods which seem crucial in the particular case of the GMBF huller are: joint design via a multi-player system, the strong interactions between researchers and key system players, a strong desire for innovation among the women processors - the future users of the huller - involvement by research which extended beyond the project's lifetime, and involvement by NGOs in disseminating the innovation on a wider scale.

Activity 5.3. *Supporting innovation processes*

Under this activity, the WP4 team supported two activities carried out by WP3: on the one hand "Manufacture and field trialling of a hydrolift prototype degritter" and on the other hand "Transfer of the CSec-T dryer to the field in Burkina Faso".

The system set up in Bobo Dioulasso, an innovation platform which was able to obtain certain results (presented in paragraph 2.2.3), was based on putting together a set of players comprising 2 dryer manufacturers (M. Ouattara and A. Souaré from SOLDEV), women fonio processors from the cereal processing network RTCF, F. X. Traoré (UTF, based in Bobo) the number one processor in the sector, the NGO Aprossa-Afrique Verte and researchers from IRSAT and Cirad.

This system brought together various players who for the most part had never met. This was the case in particular for the equipment manufacturers and women fonio processors (potential users). Another aim was to generate interactions between researchers and key players capable of make a big contribution to disseminating innovations through setting up learning scenarios: training equipment manufacturers in manufacturing the CSec-T dryer, and training the women processors in using the dryer.

Simply communicating research results is not sufficient for them to be used. The main point was to make the research results accessible.

The manufacture of two CSec-T dryers in the workshop of SOLDEV meant that the equipment could be adapted to local manufacturing conditions, and the manufacturing cost evaluated. The training sessions bringing together manufacturers, women processors, researchers and NGOs provided an understanding of the appropriation conditions. Exchanges with the various players also helped the researchers define the ways of harnessing the research results. In addition to the 2 dryers manufactured with Aval Fonio project funding, SOLDEV manufactured and sold 3 other dryers for women processors from Bobo Dioulasso and Banfora.

Partial conclusion

The innovation dissemination support system set up in Bobo Dioulasso (Burkina Faso) has only been in place since the end of 2015. Although recent, it has already given some encouraging results, and needs support.

This type of system is largely inspired by the innovation platform concept, as well as the findings of the GMBF fonio huller innovation case study. Through this approach, the objective is to answer the question of how to promote access and actual use of agribusiness innovations by SMEs for the purpose of boosting the sector's productivity, contributing to economic growth and thereby contributing to food security and poverty reduction.

There are already a number of innovation platform trials in Africa. Most are focused on agricultural activities, and put the producers at the core of the system. Yet few innovation platform trials are focused on technological innovation in agribusiness. This sort of system, networking the various players capable of playing a role in the design and adaptation of the innovations, seems promising in the field of agribusiness technological innovations.

The challenges for research are to:

- Design new technical references

- Build up the knowledge of the SMEs: women processors and equipment manufacturers

- Renew interactions between the local players

- Support the innovation processes.

2.2.5. **WP5: Facilitation, coordination and communication**

A 6-month project extension request was issued on 3 March 2015 to the African Union by the Cirad coordinators. A positive reply was received by a letter from the African Union (Ref.: HRST/ST/1/1461.10.15) dated 5 October 2015. The originally scheduled closing date of the project (16 December 2015) was deferred to 16 June 2016.

Activity 6.1: *Creating a website to inform the players*

The project website, which went online in September 2013, was regularly updated throughout the project. It comprises a French version (http://aval-fonio.cirad.fr/) and an English version (http://aval-fonio.cirad.fr/en).

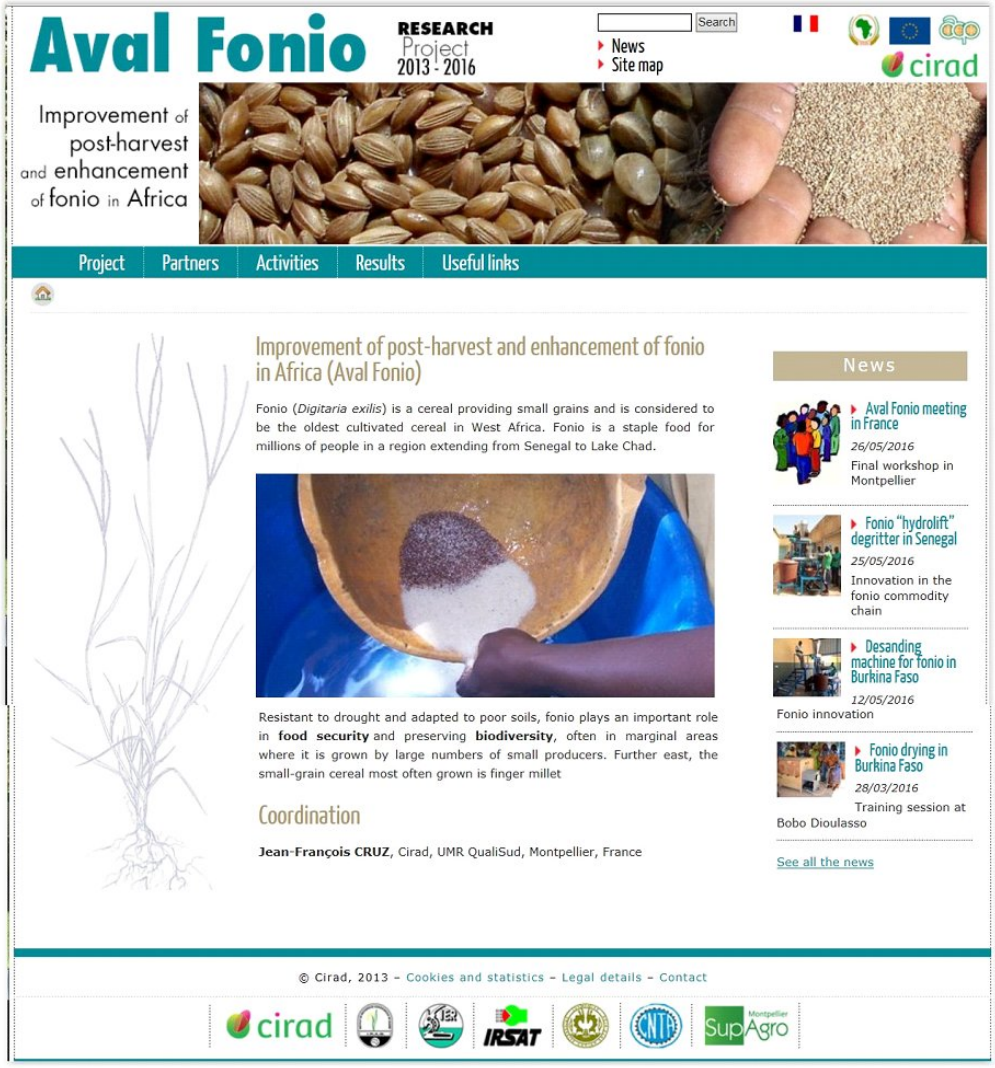


Figure 56. View of the home page of the Aval Fonio site (© Cruz, Cirad)

Activity 6.2: *Organising a seminar, inviting other producer countries*

This activity was replaced by the final meeting, which was held in Montpellier (France) in June 2016.

Activity 6.3: *Publication of results in the form of articles and a CD-ROM*

The partners were encouraged during the project to publish outreach articles, short "journalistic" pieces, posters, etc. to raise awareness of fonio in general and/or of the results obtained under the Aval Fonio project in particular.

An article entitled "*La mécanisation du décorticage du fonio a réduit la pénibilité et contribué à la durabilité de la filière*" ["Mechanisation of fonio hulling has reduced workload and contributed to the

sustainability of the industry"] was drawn up for the book "Développement durable et filières tropicales" ["Sustainable development and tropical industries"] published in 2016 by Editions QUAE.

An Aval Fonio project presentation brochure was produced for the African Union. It is available in French and English versions.

An article "*Fonio et Quinoa, deux nouvelles graines à la conquête des marchés*" ["Fonio and Quinoa, two new grains on the lookout for markets"] is currently being drafted for publication in the review "Agronomie, environnement et sociétés" of the French association for agronomy.

The book "*Fonio, an African cereal*" was published in July 2016 (Editions Cirad, IRAG).

This book is the updated English version of the book "Le fonio, une céréale africaine" published in 2011 by Editions QUAE. Dedicated to fonio, this book addresses all aspects of this small cereal, from cultivation to processing, and even provides some recipes. It provides a summary of around twenty years' research conducted in West Africa, under international projects.

Reference: *Cruz J-F, Béavogui F., Dramé D., Diallo T.A. 2016. Fonio, an African cereal. Editions Cirad/IRAG, Montpellier, France, 153 p.*

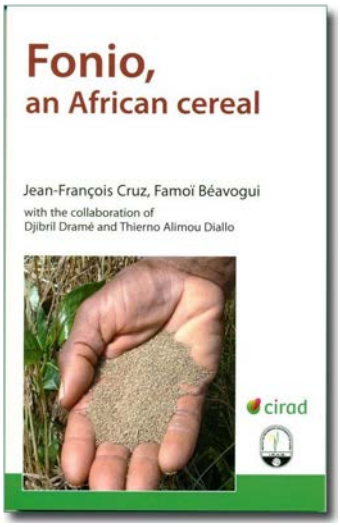


Figure 57. "Fonio, an African cereal" (© Cruz, Cirad)

An Aval Fonio CD-ROM is under preparation to bring together all the project deliverables.

Finally, a short documentary film about fonio has achieved:

Reference: *Morlet N., with the collaboration of Cruz J.-F., Fonio, 2016.*

Activity 7.1: *Organising and facilitating specific workshops and the annual meetings*

✓ *2015 annual meeting in Ouagadougou (Burkina Faso).*

In 2015, the Aval Fonio project annual meeting was arranged in Ouagadougou (Burkina Faso) from 19 to 23 January 2015. Organised jointly by Cirad and IRSAT, the meeting was held on the new premises of the Cirad Regional Directorate within IRD Burkina.

The annual meeting brought together all the project partners (Cirad, Irsat, IER, ESP-Ucad, CNTA), with the exception of IRAG from Guinea, which was unable to get to Burkina Faso. It provided an opportunity to analyse the state of progress of the activities of the various work packages and schedule the activities for the third year of the project. It also provided an opportunity to visit fonio processing equipment manufacturers (Remico and Agri-équipement) in Ouagadougou.

Figure 58. Aval Fonio project 2015 annual meeting in Ouagadougou (© T. Ferré, Cirad)

✓ *Work packages workshop in Dakar (Senegal)*

Cirad, in partnership with ESP-UCAD, arranged a work packages workshop in Dakar (Senegal) from 8 to 12 June 2015. This was the seventh meeting held under the Aval Fonio project.

The meeting brought together twenty or so participants, including researchers and technicians from ESP-UCAD–Senegal (8), Cirad-France (5 researchers), IRAG-Guinea (3 researchers), IER-Mali (2 researchers) and IRSAT-Burkina Faso (1 researcher).

The opening of the workshop was chaired by A.T. Gaye (new Director of ESP/UCAD), D. Depommier (Cirad Regional Director), P. N. Sall (Managing Director of FNRAA), F. Béavogui (Managing Director of IRAG), C.M.F. Kébé (Aval Fonio supervisor for Senegal) and J-F Cruz (Aval Fonio project Coordinator).

The discussions reviewed the results of the research conducted in mechanisation of the fonio post-harvest segment, and scheduled the future activities up to completion of the project. The workshop also provided the opportunity to conduct a drying trial on 350 kg of precooked fonio in the greenhouse dryer (CSec-S) designed by Cirad and tested at ESP-UCAD (see § 2.2.3).

Figure 59. Participants at the Dakar workshop in June 2015 (© T. Ferré, Cirad)

The workshop was covered by a specific report:

Reference: *Cruz J-F., Kébé C. M. F., 2015. Report on the Aval Fonio workshop, Dakar (Senegal). Aval Fonio project. Cirad, Montpellier, 33 p.*

✓ *2016 annual meeting in Dakar (Senegal).*

The third annual meeting of the Aval Fonio project was held in Dakar (Senegal) from 1 to 5 February 2016.

Arranged by Cirad and ESP-UCAD, the meeting was held on the premises of the incubator Innodev at the Polytechnic Higher Institute (Cheikh Anta Diop University).

The annual meeting concerned all the project partners, and brought together a dozen participants. Cirad was represented by UMR QualiSud (J-F Cruz, Coordinator; and T. Goli, co-supervisor of WP3) and Innovation (T. Ferré, co-supervisor of WP4). ESP-UCAD from Senegal was represented by C. M. F. Kébé (co-supervisor of WP3 and project representative in Senegal), A. Anne and A. Diallo from WP3. The other partners present were IER from Mali (Ms. F. Guindo, co-supervisor of WP3), IRAG from Guinea (T.A. Diallo, co-supervisor of WP2; and S. Camara, co-supervisor of WP1) and IRSAT from Burkina Faso (I. Medah, co-supervisor of WP4).

The object of the Dakar annual meeting was to analyse the results of the various activities carried out in 2015 and schedule the activities up to the project closure planned for 16 June 2016. It also provided an opportunity to address the administrative and financial aspects of the project and decide on a final meeting in Montpellier (France).

Figure 60. Participants at the Dakar annual meeting in June 2015 (© T. Ferré, Cirad)

- ✓ ***Aval Fonio project final meeting in Montpellier (France).***

The Aval Fonio project final meeting was arranged by Cirad in Montpellier (Maison de la Technologie) from 6 to 10 June 2016, bringing together fifteen or so participants.

The annual meeting concerned all the project partners. Cirad was represented by UMR QualiSud (J-F Cruz, Coordinator; T. Goli, co-supervisor of WP3; and P. Thaunay, Co-supervisor of WP2) and Innovation (T. Ferré, co-supervisor of WP4). ESP-Ucad from Senegal was represented by C. M. F. Kébé (co-supervisor of WP3 and project representative in Senegal), A. Anne and A. Diallo from WP3. The other partners present were IER from Mali (Ms. F. Guindo, co-supervisor of WP3), IRAG from Guinea (S. Camara, co-supervisor of WP1) and IRSAT from Burkina Faso (I. Medah, co-supervisor of WP4). Researchers and technicians from QualiSud who had collaborated in the project were also able to take part in certain presentation and discussion sessions.

From left to right: 2nd row: T. Ferré (Cirad), Ms. F. Boré Guindo (IER, Mali), J-F Cruz (Cirad), Ms. V. Bancal (Cirad), A. Diallo (ESP, Senegal), S. Camara (IRAG, Guinea), P. Thaunay (Cirad), I. Medah (IRSAT, Burkina Faso)
1st row seated: C.M.F. Kébé (ESP, Senegal), A. Delpech (Cirad), T. Goli (Cirad), A. Anne (ESP, Senegal)

Figure 61. Participants in the Aval Fonio project final meeting, Montpellier (© A. Servent, Cirad)

The final meeting drew up a detailed report of the numerous activities carried out under the Aval Fonio project, especially:

- Analysis of fonio production and post-harvest systems,

- Mechanisation of fonio post-harvest techniques (threshers and cleaners),

- Improving processing and stabilisation techniques (degritters and dryers),

- Innovation process in small processing plants.

The meeting also provided an opportunity to introduce the Southern partners to the various technical facilities of Cirad's Agri-food Platform.

Activity 7.2: *Training the partners*

In 2013, a training session entitled "Equipment design methods" was conducted in Senegal by Cirad (P. Thaunay), at the request of the partner ESP-UCAD.

In 2016, a training session on how to use the CSec-T dryers was conducted in Bobo Dioulasso for fifteen or so fonio processors from western Burkina Faso and Ouagadougou. It was arranged at IRSAT in Bobo Dioulasso, and conducted by the researchers and technicians from Cirad, IRSAT, ESP-UCAD and in collaboration with the NGO Afrique verte Burkina - Aprossa.

During the project and the validation of the various equipment (dryers, degritters, etc.), Cirad and its partners were able to train the equipment manufacturers and fonio processors in the manufacture and use of the equipment.

2.3. Modified activities

2.3.1. WP1: Analysis of production and post-harvest systems

There were no major delays in the execution of the WP1 activities.

2.3.2. WP2: Mechanisation of fonio post-harvest techniques

The delays observed during the first 2 years of the project were reduced, and all the planned trials were carried out.

2.3.3. WP3: Improvement of fonio processing and stabilisation techniques

The cumulative delays from the first 2 years of the project were also reduced for this package, and all the planned trials were carried out, thanks in particular to the 6-month extension of the project. In this way the transfer and field tests of the CSec-T "cross-flow" dryer and CSec-S "greenhouse" dryer in Senegal, Burkina Faso and Guinea took place during Q1 2016.

In terms of mechanisation of fonio degritting, the first "hydrolift" prototype degritter was manufactured and field tested on the premises of UCODAL in Bamako (Mali) during 2015.

Thanks to the 6-month extension of the project, a second prototype and a pilot lot of two hydrolift degritters were made to equip 3 other fonio processing SMEs, in Mali, Burkina Faso and Senegal respectively.

2.3.4. WP4: Innovation process in small processing plants

There were no particular delays in the execution of the WP4 activities.

2.3.5. WP5: Facilitation, coordination and communication

In 2015 and 2016, modifications were made to activity 7.1. *Organising and facilitating specific workshops and annual meetings*.

In the 2014 annual report, the provisional schedule for the project meetings and workshops was updated as follows (table 6):

Table 6. Meetings and workshops calendar updated in 2014.

Meetings or workshops	Country	Participants	Month	Duration (days)
Annual meeting	Burkina Faso	Steering Committee + local partners	January 2015	3
WP1 to WP4 workshop	Senegal	Researchers + local partners concerned	June 2015	3
WP1 to WP4 workshop	Burkina Faso	Researchers + local partners concerned	November 2015	3
Annual meeting	Guinea	Steering Committee + local partners	January 2016	4
Final seminar	Mali	Steering Committee + Researchers, local partners, decision makers, NGOs, etc.	March 2016	4

Because of the security and/or sanitary situation in certain partner countries (especially Guinea and Mali), the Steering Committee modified the meetings calendar for the end of the project (table 7).

Table 7. Calendar of workshops and meetings held in 2015 and 2016.

Meetings or workshops	Country	Participants	Month	Duration (days)
Annual meeting	Burkina Faso	Steering Committee + local partners	January 2015	3
Work packages workshop	Senegal	Researchers + local partners concerned	June 2015	3
Annual meeting	Senegal	Steering Committee + local partners	February 2016	4
Final meeting	France	Steering Committee + Researchers	June 2016	4

2.4. Aval Fonio project results.

Observations on the execution and achievement of the activities

As was already specified in previous annual reports, certain technical activities may have been substantially delayed in their execution because the security and/or sanitary situation in some partner countries (Guinea, Mali, or even Burkina Faso, etc.) disrupted the launch or smooth running of the actions.

The WP1 surveys on fonio production and post-harvest systems in Guinea in the end proceeded more or less as planned despite the country at one time being hard hit by the Ebola virus. In 2015-2016, the WP1 activities “Analysing production and post-harvest systems” initiated in 6 big villages in Fouta Djalon were extended to the Lélouma and Mali zones to the west and north of Labé.

For WP2 “Mechanisation of post-harvest techniques”, the various planned activities were completed with very interesting results, although not all positive.

The fonio motor mower, modified in Bamako in July 2015, was tested in Guinea, but the results were dissatisfactory. So some further studies are required, with a view to mechanisation of fonio harvesting in the long term.

Fonio threshing tests were carried out. The Ricefan thresher was tested in Mali and Guinea, but the results were mediocre. The new trials conducted with the reconditioned ASSI thresher confirmed the good results already obtained during the previous fonio projects. Following on from the very good results obtained with the modified ASSI thresher, the mechanisation specialists have validated the machine for threshing fonio, and consider that it also seems economically profitable, especially under conditions in Guinea. The current machine, which is relatively bulky, may be suitable for easily accessible plain zones. For mountain zone, more compact threshers of the same type would need to be used, for ease of transport.

The cleaning trials with the rotary screen and winnowing channel confirmed the good performances of this equipment. Following on from the very good results obtained (throughput around 400 kg/h), the mechanisation specialists have validated this equipment for cleaning paddy fonio, and consider that it can be used for cleaning hulled and whitened fonio; the winnowing channel is also often coupled to the GMBF huller-whitener. The rotary screen and winnowing channel are versatile pieces of equipment which can be used on other cereals. Now both machines should be manufacturable by local tradesmen, thereby ensuring their distribution across numerous West African countries.

The technical results of WP3 “Improvement of fonio processing and stabilisation techniques” were the most numerous and the most innovative.

For activity 3 (mechanisation of washing and degritting), it was demonstrated by tests in Montpellier and Bamako that use of a simple electrical “cement mixer” type washer could implement an excess water mixing principle, similar to the one used in traditional manual washing of fonio. For degritting, the “hydrolift” degritter, designed by Cirad, meets the specifications that the researchers had set by ensuring a throughput of around 100 kg/h and a residual grit content in the grains of less than 200 ppm. Prototypes and pilot lot equipment were set up and tested in SMEs in Mali, Burkina Faso and Senegal. The private operators are satisfied with the good performances observed under actual conditions of use.

For activity 4 “drying”, a cross-flow dryer (CSec-T) and a “greenhouse” dryer (CSec-S) were tested on the ESP-UCAD site in Dakar before being transferred to the field in eastern Senegal (CSec-T dryer to the group in Salémata and CSec-S dryer to the Koba Club group, Kédougou). The CSec-T dryer meets the specifications that the researchers had set by providing a load capacity of approximately 100 kg and a drying flowrate of 30 to 35 kg/h to dry wet processed fonio (white or precooked) from 35% to 10%. The 90 m² CSec-S greenhouse dryer equipped with 10 or more grates also meets the specifications set by providing a load capacity of approximately 300 to 350 kg for drying wet processed fonio (white or precooked) from 35% to 10% in 24 h.

Furthermore, 2 CSec-T dryers were manufactured in Burkina Faso to be installed with 2 Burkinese SMEs (in Ouagadougou and Toussiana), and a small 20 m² CSec-S dryer was set up in the village of Pilimini in Guinea. The various private operators who were able to use the CSec-T and CSec-S dryers seem to have satisfied the performances observed under actual conditions of use.

For WP4 “The innovation process in small processing plants”, the activities proceeded as planned and the “GMBF huller” innovation impact study were conducted in Burkina Faso and Mali. For the field studies, Cirad and IRSAT requested the collaboration of the NGO “Afrique Verte” (Aprossa) in Burkina Faso and of the NGO “Afrique Verte” (Amassa) and the IER (Ms. F. Guindo) in Mali.

For WP5, activities 6.1 (Website) and 7.2. (Training the partners) were carried out at the beginning of the project in accordance with the provisional programme. For the other activities some modifications were made to the calendar of the various meetings or workshops, as was described in paragraph 2.3 “Modified activities”. 2 items were modified from the initial project, relating in particular to:

A half-way point assessment mission (2 agro-machinery and socio-economics experts) to analyse the relevance of the equipment (threshers, cleaners, degritters, dryers, etc.) tested by the various fonio industry operators. Since the design and validation of the prototypes created under the project were delayed and the first equipment was not installed in the field until 2015 and early 2016, this mission became obsolete. Following the good results obtained in the first trials on the prototypes designed (“hydrolift” degritter, greenhouse dryer and cross-flow dryer, etc.), it seemed more efficient to use the funds to use the project extension to ensure better distribution of the equipment to the SMEs or groups: dryers in Senegal, but also Burkina Faso and Guinea, hydrolift degritters in 2 companies from Bamako (Mali), but also Burkina Faso (Bobo Dioulasso) and Senegal (Kédougou).

The final seminar had been arranged to be held in Ouagadougou (Burkina Faso). However given the terrorist attacks which took place in this city in January 2016, the project Steering Committee which met in Dakar in February 2016 decided against arranging a final seminar, and to replace this event with a final meeting of the project partners in Montpellier (France).

In terms of publications, certain results from the Aval Fonio project were covered by posters presented at various occasions, and were used to update the book “Le fonio, une céréale africaine” published in 2011 by Editions QUAE. This led to the publication of the English version entitled “Fonio, an African cereal” in July 2016 (Editions Cirad, IRAG).

2.5. Updated action plan (2016)

Not applicable, since the Aval Fonio project closed on 16 June 2016.

3. Partners and other cooperation

3.1. Relations between the Aval Fonio project partners

During this period, the coordinators did not encounter any particular difficulties with the partner institutions in executing the Aval Fonio project. On the contrary, the coordinators can be pleased at the interest, vigour and good spirit of collaboration demonstrated by all the work package supervisors and all the agents involved in the project. For the coordinators, the main difficulty throughout the project was not having the opportunity to travel to Guinea, the main fonio producer country, to meet directly with the partner IRAG and the fonio industry operators.

3.2. Relations with the State authorities in the project countries

As in previous years, the main difficulties encountered in 2015 and 2016 were due to the difficult security or sanitary situations in certain partner countries such as Mali, Guinea or Burkina Faso.

3.3. Relations with any other organisation involved in the project implementation

- **Associates**

The National Centre for Agribusiness Technology (CNTA), Burundi. In January 2015, a specialist in post-harvest technologies from CNTA (S. Ntahomvukiye), was invited to participate in the Aval Fonio project annual meeting held in Ouagadougou (Burkina Faso). A study mission to Burundi was planned by Cirad (J-F Cruz) for 2015 or 2016 to carry out a review of the finger millet industry in collaboration with CNTA. Yet because of the growing insecurity prevailing in this country since early 2015, this mission was deferred several times, and ended up being cancelled.

- **End beneficiaries and target groups**

A host of private partners were associated with the project, especially producers, processors and women's associations unified in groups, equipment manufacturers, etc.

In Guinea, it was more the fonio producers which were associated from the beginning of the Aval Fonio project, since the WP1 activities related to the upstream segment. Particular attention was paid to the village of Donghel Sigon in Fouta Djallon (Mali prefecture), where the producers own two large areas of 170 ha and 250 ha, currently dedicated to fonio cultivation. Under WP2, a mechanical workshop from Labé (Mr. Thierno Bela) was closely involved in the modifications made to certain equipment. Finally a group of women from the village of Pilimini (Koubia prefecture, Fouta Djallon) had a small-sized CSec-S greenhouse dryer installed.

In Senegal, it was women processors' associations, unified in groups, which closely collaborated with the project through their involvement on the one hand with the CSec-T cross-flow dryer trials (group in Salémata), and on the other hand with the installation and monitoring of the CSec-S greenhouse dryer and hydrolift degritter (Koba Club group, Kédougou). The Mamba Guirassy technical institute in Kédougou also contributed to the final assembly of the hydrolift degritter.

In Mali, as in previous fonio projects, very close collaboration was established with the equipment manufacturer IMAF, which was involved in the activities from the beginning of the project. The joint actions in particular related to the manufacture or modification of numerous pieces of equipment or prototypes tested under the project: motor mower, Ricefan thresher, winnowing channel, rotary screen, "hydrolift" prototype degritters. Other equipment manufacturers were also able to participate in certain activities, such as MOD Engineering or the tradesman Nana Philémon. Several SMEs from Bamako were also closely involved in the various field tests conducted. These included in particular UCODAL, Danaya Céréales and Dado Production. These SMEs are the three leading fonio processing companies in Bamako (Mali) (see § 2.2.4).

In Burkina Faso, meetings were held with more than twenty mechanical manufacturing workshops in Bobo Dioulasso and Ouagadougou during surveys conducted under WP4. Very close collaboration was established with the equipment manufacturers SOLDEV and A. Souaré in Bobo Dioulasso for manufacturing CSec-T dryers and the partial production and the assembly of the hydrolift degritter. Special collaboration was also established with the fonio processing unit (UTF) newly established in Bobo

Dioulasso, where the hydrolift degritter was installed and which invested in a CSec-T cross-flow dryer. Fifteen or so fonio processors from western Burkina Faso and Ouagadougou received a training session on how to use the CSec-T dryer. Two SMEs, "Tout Super" in Toussiana and EOBA in Ouagadougou, were selected to receive CSec-T dryers because of their long-standing collaboration with the researchers who since the early 2000s have been working to improve the fonio industry in West Africa.

- **Other third parties involved (NGOs, etc.)**

Under the Aval Fonio project activities, and especially for WP3 and WP4, the researchers have closely collaborated with NGOs, such as in Burkina Faso with the NGO Afrique Verte, Aprossa *(Association for the Promotion of food security and sovereignty in Burkina)*, in Mali with the NGO Afrique Verte, Amassa *(Malian association for food security and sovereignty)* and Guinea with the NGO ADESAG (*Association for the development of socially responsible enterprise in Africa and Guinea*).

4. Visibility

The project document refers to various actions planned to raise the profile of the contribution of the African Union and European Union to the Aval Fonio project.

4.1. Aval Fonio project website

The website (in French and English) dedicated to the Aval Fonio project (http://aval-fonio.cirad.fr/projet/presentation) refers to the funding granted by the African Union (EuroAid procedure), and links to these institutions have been set up.

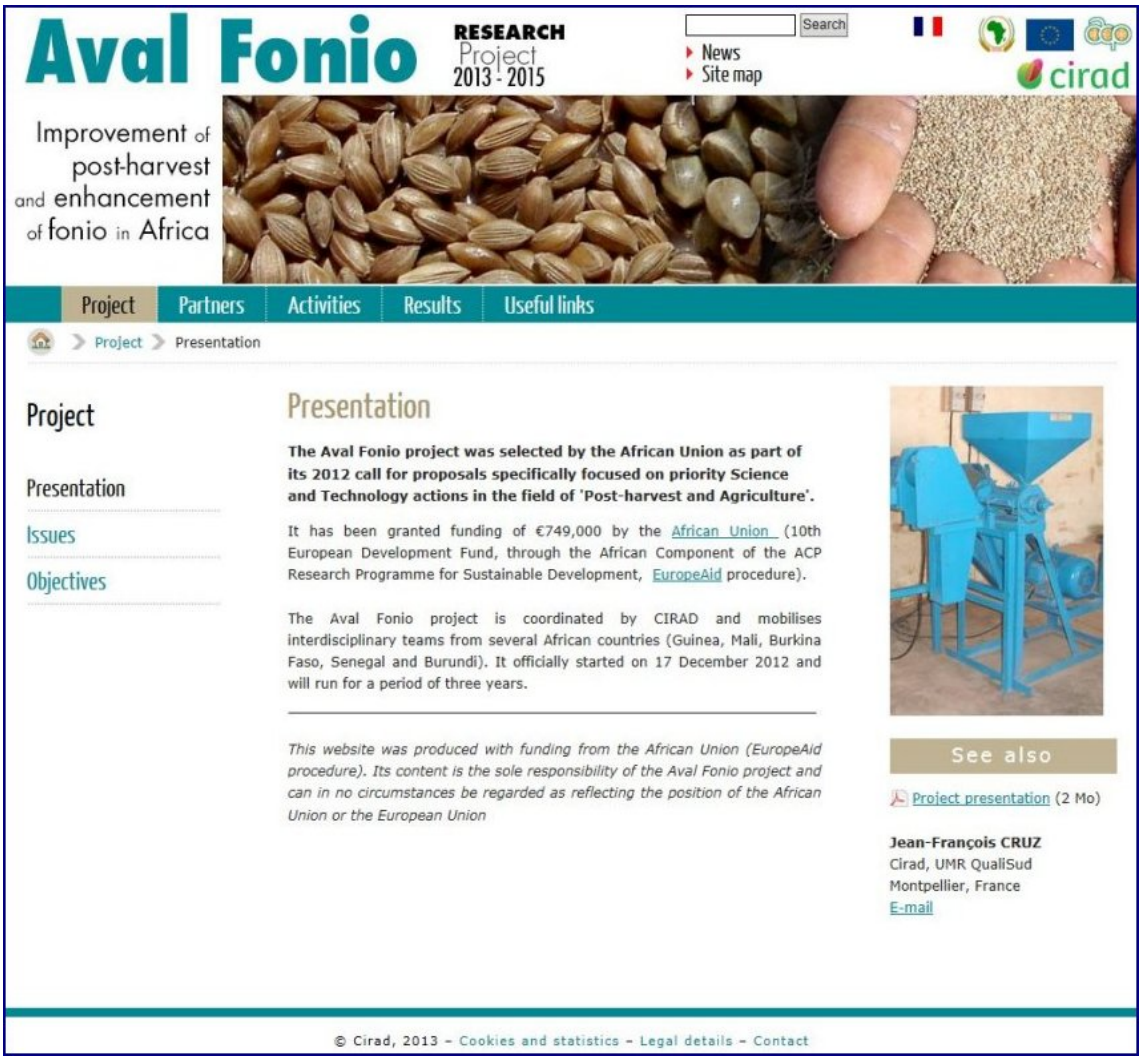


Figure 62. Screenshot of "presentation" page of the Aval Fonio website (© Cruz, Cirad)

4.2. Publications and other works

In 2011, a book entitled "*Le fonio, une céréale africaine*" was published by Editions QUAE. This document, the first book dedicated exclusively to fonio, addresses all the aspects of this small cereal, from cultivation to processing.

Reference: *Cruz J-F, Béavogui F., Dramé D., 2011. Le fonio, une céréale africaine. Editions Quae, CTA Wageningen, Presses agronomiques de Gembloux. 175 p.*

In July 2016, the English version entitled "*Fonio, an African cereal*" was published (Editions Cirad, IRAG). This work summarises around twenty years of research conducted in West Africa, under various international projects including the Aval Fonio project.

Reference: *Cruz J-F, Béavogui F., Dramé D., Diallo T.A. 2016. Fonio, an African cereal. Editions Cirad/IRAG, Montpellier, France, 153 p.*

A short documentary film was also produced:

Reference: *Morlet N. Cruz J.-F., Fonio, 2016.*

4.3. Receiving visitors at the Cirad agrifood technology platform

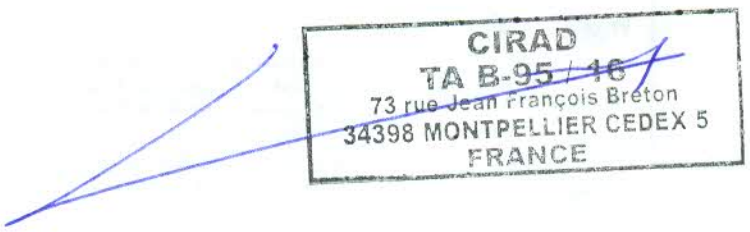
The Cirad agrifood technology platform receives a host of visitors all year round, and takes part in the Science Festival held in France in October. At each event, the Aval Fonio Project Coordinator (Cruz J-F.) presents to dozens of visitors the theme "Rice and fonio in all their states", broadly covering fonio post-harvest research technologies, and referring specifically to the Aval Fonio project.

The European Commission may wish to publicise the results of Actions. Do you have any objection to this report being published on the EuropeAid website? If so, please state your objections here

No objections

Name of contact person for the Aval Fonio project: CRUZ, Jean-François

Signature:



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